EVALUATION OF VARIABLE MESSAGE SIGNS IMPACT ON CONGESTED STREETS

BY

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In the Name of Allah, Most Gracious, Most Merciful

DEDICATED
TO MY FATHER, MOTHER, WIFE,
CHILDREN AND TO MY BROTHER AND SISTERS

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First of all, I thanks Allah for all the blessings, he bestowed on me and continues to bestow on me. I'd like to provide my appreciation to my instructors in KFUPM, especially my supervisor Prof. Nedal Ratrout whose support and encouragement was a great factor for my success.

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ABSTRACT

Full Name : YAZAN FARTD ABDULHADI ISSA

Thesis Title : EVALUATION OF VARIABLE MESSAGE SIGNS IMPACT ON CONGESTED STREETS

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Variable Message Signs (VMS) is a common technique used for informing drivers about the traffic conditions ahead and advise them how to cope with it. Recently, VMS was introduced in Saudi Arabia in few locations by displaying general static information messages not related to the instantaneous traffic conditions, for testing its reliability under local conditions and to familiarize local drivers with this technology.

This study aimed to evaluate the possible response of the drivers to VMS when used for messages related to road traffic conditions, and to evaluate the effect of some personal characteristics of the drivers that control their choice to adjust their travel route. A major arterial in Al-Khobar city in Saudi Arabia with a massive VMS board was selected for this study (Prince Turkey Bin Abdulaziz Road). The VMS board is located 0.75 km before a very busy signalized intersection. The arterial has a service road parallel to it with an exit slip ramp 70 meters after the VMS board. This VMS is used occasionally to display general information messages not related to traffic along this arterial.

The evaluation followed two approaches. First, an interview was done with 250 drivers selected randomly from the area in the vicinity of the studied arterial. About 77% of the

interviewed drivers indicated that they will react positively to VMS if used in the field to relay messages related to the instantaneous traffic conditions. In the second approach, a real experiment was conducted along this arterial. The percentage of the traffic diverted from the arterial to the right using the slip exit ramp was monitored during congested periods for several days.

Following that, the VMS was activated for several days to advise drivers who want to make a right turn at the signalized intersection to use the exit slip ramp when the intersection is very busy and the right turning lane is blocked with very long queues. The percentage of diverted traffic to the service road at the same slip exit ramp during the same congested periods was monitored for several days. It was found that the percentage of diverted traffic during the display of VMS message is 3-8% higher than the percentage of diverted driver without activating the VMS. This difference was statistically significant at 90% confidence level.

Even the above percentage looks low, the traffic simulation showed reasonably good improvement of VMS use by reducing delay and fuel consumption, especially in the long time scale (such as one year). The possibility of using VMS as a tool for dynamically lane assignment at signalized intersection 'which was indicated through ARENA simulation proved to be quite promising.

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ملخص الرسالة

الاسم الكامل: يزن فريد عبد الهادي عيسى

عنوان الرسالة: تقييم اثر اللوحات الالكترونية المتغيرة في الطرق المزدحمة

التخصص : الهندسة المدنية

تاريخ الدرجة العلمية: يونيو 2013م

تستخدم اللوحات الالكترونية المتغيرة (VMS) لإعلام السائقين عن حالة الحركة المرورية اللحظية. وقد تم مؤخرا استخدام هذه اللوحات في المملكة العربية السعودية واختبارها في بعض المواقع عن طريق عرض معلومات عامة عن السلامة ليس لها علاقة بوضع الحركة المرورية. وتهدف هذه الدراسة إلى تقييم استجابة السائقين للوحات عند عرضها رسائل متعلقة بأوضاع الحركة المرورية على الطرق، وتقييم تأثير بعض خصائص السائقين الشخصية للسائقين التي تتحكم في مدى استجابتهم للوحات. وقد تم اختيار طريق شرياني (الأمير تركي - الكورنيش) في مدينة الخبر في المملكة العربية السعودية الذي يحمل لوحة الكترونية لهذه الدراسة. حيث تقع اللوحة الالكترونية قبل تقاطع مزدحم محكوم بإشارة ضوئية بحوالي 750 مترا، ويوجد طريق خدمة مواز للشارع الرئيسي ويمتد على طوله، مع مخرج يقع على بعد 70 متر بعد اللوحة الالكترونية.

وقد تم إتباع مسارين للتقييم، الأول: عن طريق إجراء مقابلة مع 250 سائقا تم اختيارهم عشوائيا من مناطق في محيط منطقة الدراسة. وقد تبين أن حوالي 77٪ من السائقين الذين تمت مقابلتهم أفادوا بتعاملهم بإيجابية مع معلومات اللوحات إذا ما استخدمت في الموقع لنقل الرسائل المتعلقة بأوضاع الحركة المرورية. وفي المسار الثاني، فقد أجريت تجربة حقيقية على الطريق الخاضع للدراسة، حيث تم رصد نسبة السائقين المنتقلين من الطريق الرئيسي إلى طريق الخدمة باستخدام المخرج خلال فترات الازدحام لعدة أيام.

وبعد ذلك، تم تفعيل اللوحة الالكترونية على الطريق لعدة أيام لتوجه السائقين لسلوك طريق الخدمة إذا كان متجها إلى اليمين في حالة كان التقاطع مزدحما جدا والمسرب الأيمن مغلقا. وتم رصد نسبة السائقين المنتقلين من الطريق الرئيسي إلى طريق الخدمة باستخدام نفس المخرج. وقد وجد أن النسبة المئوية للسائقين المنتقلين خلال عرض اللوحة للرسالة هو أكبر بنسبة 8٪ من انتقال السائقين في حالة عدم تفعيل اللوحة، وقد اثبت هذا الاختلاف إحصائيا عند درجة ثقة 90٪. كما تم تقييم هذا الاختلاف في برامج المحاكاة المرورية TRANSYT-7F، وأشارت النتائج إلى وجود تحسن في فعالية الحركة المرورية على الطريق، حيث تم تقليل التأخير، وعدد مرات التوقف، واستهلاك الوقود. كما تم تقييم تأثير استخدام تقنية اللوحات الالكترونية المتغيرة من خلال تطبيق مفهوم استخدام مسارب الحركة المتغيرة تبعا للازدحام المروري في برنامج المحاكاة المرورية ARENA، حيث أشارت النتائج إلى أن استخدام اللوحات بنسبة التحسن السابقة يقلل من نسبة استخدام السائقين للمسارات الخاطئة.

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CHAPTER 1

INTRODUCTION

1.1 Background

Development of any country now is related to the power and maturity of the transportation segment. Living in any place without streets that connect cities with other cities or villages is not possible. Use of any transportation mode is necessary to enhance accessibility. Therefore, transportation has to be considered as an essential and basic component of any comprehensive development plan.

Traffic congestion continues to grow along Saudi Arabian roads. Motor vehicles are exposed to excessive delay, which degrades the air quality. Traffic congestion is being recognized as one of the most significant problems in urban areas worldwide including Saudi Arabia. The population of Saudi Arabia exceeded 27 million and traffic accidents in 2011 reached around 544,000 (Ministry of Interior, 2011).

Traffic congestion adversely impacts the movement of people and goods. Congestion problems appear to be long term. If the traffic is acceptable these days, the roads eventually will not be able to carry the new traffic volumes due to traffic growth, and congestion problems will arise. Congestion is of two categories, recurring and nonrecurring components, based on the primary causes at any given period of time when demand exceeds capacity. Recurring congestion occurs every day and at the same location when demand exceeds the available capacity. Road users expect this kind of congestion and they adjust their behavior accordingly. That is why this congestion is sometimes referred to as “expected congestion”.

Nonrecurring congestion results from random incidents, such as accidents, stalled vehicles, severe weather, special events, and work zones that cause unexpected delays. Road users’ reaction to this type of congestion varies and depends on each driver behavior. Their behavior might be the cause for this kind of congestion in some instance.

Congestion can be managed either through controlling the supply side or the demand side. Building new roads and widening the existing traffic networks is greatly costly and environmentally damaging. Depending on the supply side may lead to the increase in demand. Traffic engineers have frequently believed in controlling the demand side of the problem, especially in urban areas, by applying a set of congestion management techniques such as the use of variable message signs.

Congestion management techniques include the use of intelligent transportation systems (ITS). One of the most widely used mechanisms of ITS is the variable message signs (VMS). This technique assists road users in making more accurate decisions to avoid congestion by their en-route path selection.

VMS are the most visible traffic control devices that provide real-time traffic information about congestion ahead or probable delays to the drivers. One of the VMS uses is intended to modify roadway travel choices through en-route diversion. Drivers’ behavior and response mainly change based on VMS content, whether to continue on their route or choose an alternative road. A high route diversion rate can reduce congestion, improve safety, and enhance movement efficiency.

1.2 Problem Definition

Traffic congestion has become a major concern in the Kingdom not only near CBD (central business district) areas but also along major streets. Motorists need accurate travel information to help them make better decisions on departure times and routes to avoid congestion. One of the techniques that are used to meet such need is the development of VMS.

The traffic status in Saudi Arabia has special characteristics. There is a considerable amount of young drivers who have certain habits in driving, making them more prone to violate traffic regulations. There are large numbers of expatriate drivers coming from several nations for work. Most of these drivers have communication problems since they cannot read or understand Arabic or English which are the two languages used to display messages to drivers on signs or VMS, and some of them are not familiar with the road network. There are limited mass transit services and the majority of the vehicles are passenger cars. The number of driving license in Saudi Arabia has reached 3.9 million, around 56% of which are for expatriate drivers (Al-Washykree, 2012).

Recently, VMS was introduced in Saudi Arabia in few locations by displaying general static information messages not related to the instantaneous traffic condition, for testing its reliability under local conditions and to familiarize local drivers with this technology.

Several international previous studies were conducted to measure variable message signs impact by using field experimental methods or data collection based on survey (field, mail, telephone, etc.), and by group interviews. Collecting data using survey method has some restrictions since the data is collected under restricted theoretical scenarios produced by the researchers. The results are always under a scaled replay since the respondents usually change their answers with time and they mostly overstate their actual performance. In spite of these limitations, survey methods are still a useful method used to conduct such studies.

1.3 Objectives of the Study

This study aimed to enhance traffic movement efficiency in urban areas by reducing traffic congestion. This can be achieved by evaluating the effect of VMS technology usage in the study area.

The main objectives of this study can be summarized as follows:

- To evaluate the response of the drivers in Saudi Arabia to VMS technology through drivers interviews and engineering field studies.
- To generally evaluate the merits of VMS in improving traffic operations.
- To evaluate the new possible use of VMS technique as a tool for dynamic lane usage in Saudi Arabian intersections.

1.4 Study Area

A major arterial in Al-Khobar city in Saudi Arabia with a massive VMS board was selected for this study (Prince Turkey Bin Abdulaziz Road), as shown in Figure 1.1. This arterial is considered as one of the major streets in the city and has a considerable amount of traffic where a large number of drivers use it to reach the sea beach on the right side, especially in the weekend. At the time of the study, this arterial is the only arterial in the city having a VMS board.

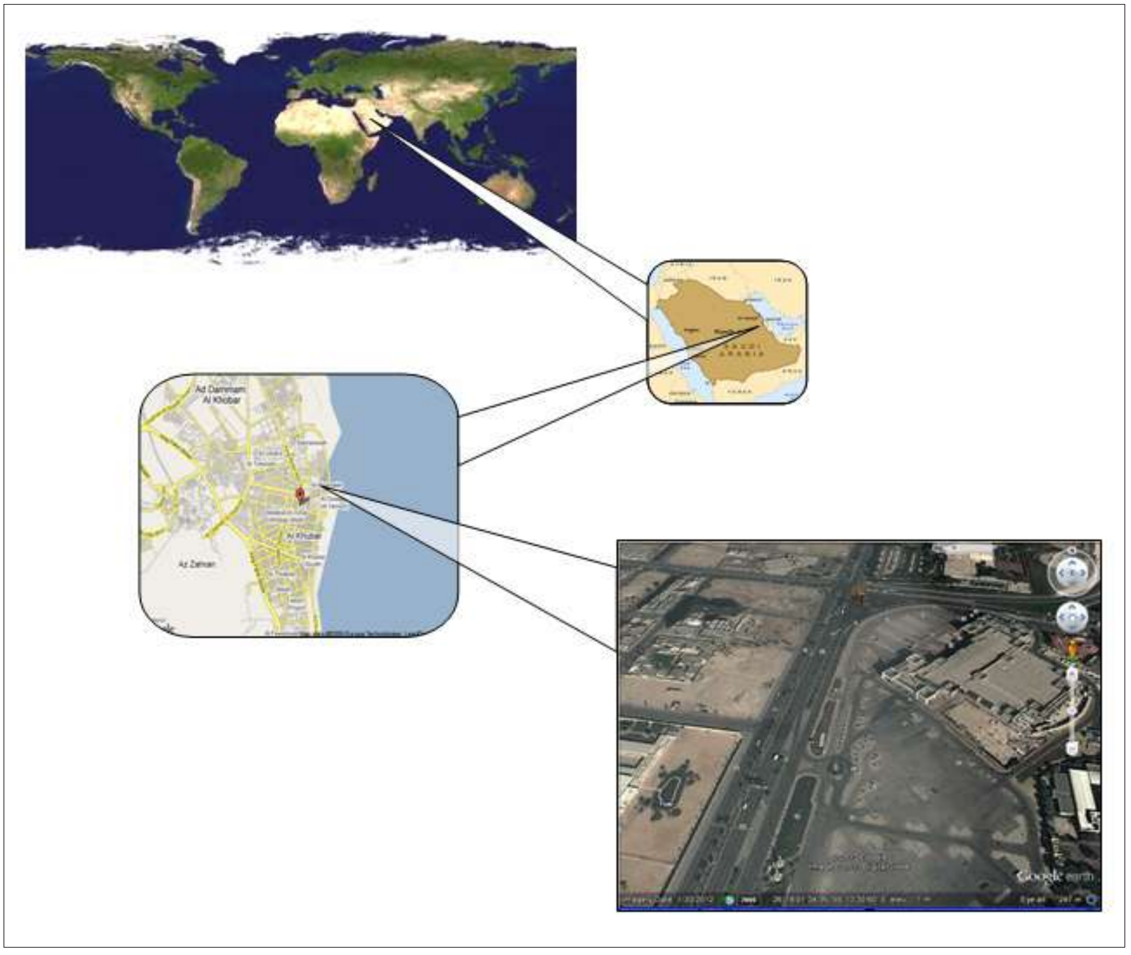

Figure 1.1: Study area (Prince Turkey Bin Abdulaziz Road).

The VMS board is located 0.75 km before a very busy signalized intersection. The arterial has a service road parallel to it with an exit slip ramp 70 meters after the VMS board, as shown in Figure 1.2. On the east side of the road is a major recreational area with several restaurants, shops and walking track, and on the west side of the arterial lie several major shops and restaurants also.

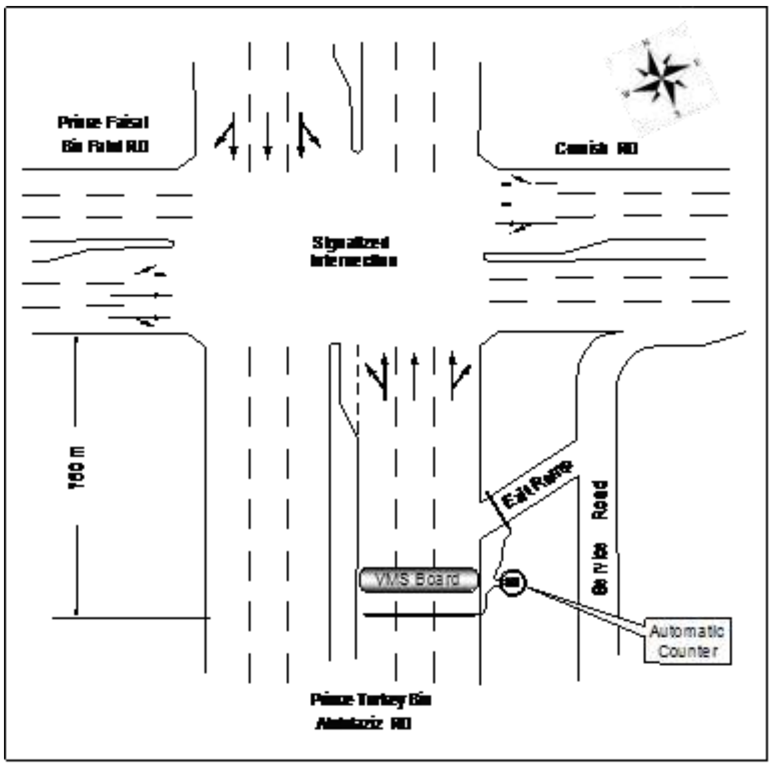

Figure 1.2: VMS location.

1.5 Methodology

This research analyzed the difference in traffic diversion percentage to an alternate route during the time the VMS displayed a message (reason for diversion) with similar measurements under normal conditions. This percentage was determined based on two approaches: drivers interviews and by conducting a real field experiment on the studied street. The methodology of this research was based on the following items:

- Literature review of the previous international studies related to the use and impact of VMS and drivers' response to VMS technology.
- Selecting proper site to conduct the research (major street with VMS board in Al-Khobar city).
- Conducting interviews with the drivers in the study area to record their familiarity and response to VMS when used for messages related to road traffic conditions.
- In the field experiment, the percentage of the traffic diverted from the arterial to the right using the slip exit ramp was monitored during congested periods for several days. After that, the VMS was activated to advise the drivers who want to make a right turn at the signalized intersection to use the exit slip ramp when the intersection is very busy and the right turning lane is blocked with very long queues. The percentage of diverted traffic to the service road at the same slip exit ramp during the same congested periods was monitored for several days.
- Statistical analysis was conducted on the results of interviews and the field experiment diversion percentage using Minitab software.
- Economical evaluation of VMS advantages by simulating the studied street using TRANSYT-7F software.
- Studying the worth of using VMS technique as a tool for dynamic lane assignment at intersections using Arena simulation software.

CHAPTER 2

LITERATURE REVIEW

2.1 Urban Congestion

Traffic congestion adversely impacts the movement of people and goods. If the road network can carry the traffic these days, it will eventually not be able to carry the extra volumes in traffic due to growth and increase in the number of road users, and congestion problems will appear. Due to congestion, motor vehicles are exposed to excessive delay, and this in turn degrades the air quality.

Traffic congestion continues to grow along Saudi Arabian roads. It is being recognized as one of the most significant problems in urban areas in Saudi Arabia. According to the Ministry of Interior (2011), the number of registered vehicles exceeded 5.7 million in 2011. This huge number of vehicles increased traffic congestion especially in urban areas even if there is a good street network (Ministry of Interior, 2011). The majority of these registered vehicles are passenger cars, and there are limited mass transit services. It is important to have a look at the techniques and tools that are used around the world for mitigating traffic congestion.

2.2 Techniques for Mitigating Urban Congestion

Congestion management is an organized process that includes procedures to monitor the transportation system's performance, identify causes of congestion, evaluate alternative actions, implement cost-effective strategies, and determine the effectiveness of those strategies which aim to enhance the mobility of people and goods.

Congestion management techniques are generally applied in two methods, either through the supply part or the demand part. Because of space limitations, trends are focused in managing the existing traffic system rather than building new facilities. Traffic management is a low-cost enhancement while building new facilities is more costly and may be faced with space limitations.

This section describes the methods for measuring congestion, factors that affect traffic congestion, and potential strategies for reducing congestion problems, including traffic demand management (TDM) strategies that reduce peak-period travel demand or improve transportation alternatives, and various ways to increase roadway capacity. TDM strategies that reduce a relatively small percentage of vehicles can provide considerable mobility enhancement.

2.2.1 High Occupancy Vehicles (HOV) Priority, Transit Improvements and Rideshare Programs

HOV priority includes strategies that support the use of bus, vanpool and carpool, like dedicated traffic lanes for HOV, queue-jumping lanes, high occupancy toll lanes, intersection controls that give priority to HOVs, preferred parking spaces or discounted parking fee provided to rideshare vehicles, favorable building access, and grade separation (Turnbull, 2001). Figure 2.1 shows HOV.

Figure 2.1: HOV.

HOV services can be evaluated using several techniques like total throughput, HOV lane utilization, travel time, safety consideration, incident rate, and traffic diversion.

2.2.2 Road Pricing

Road pricing means charging road users directly for driving on a particular road segment. It aims to manage (reduce) congestion and generate some profits. It is important to apply congestion pricing in specific periods, to reduce the traffic especially during rush hour, charging higher during heavy congestion periods, usually in the AM peak (home-work trips) and PM peak (work-home trips). It is important to know that if road pricing is implemented on just one road, it may cause the traffic to shift to other routes and therefore will increase traffic congestion on the other roads.

2.2.3 Fuel Pricing

Increasing fuel price can help reduce traffic congestion. INRIX (2008) evaluated the effects of fuel price increases on U.S. vehicle travel and traffic congestion. The results of this study indicated that increased gas prices in the first half of 2008 significantly reduced highway traffic congestion.

2.2.4 Distance Based Fees

The concept of "pay as you drive" was applied to reduce the use of private passenger cars. In this strategy, vehicle insurance and registration fees are related to distance driving. Unlike road pricing, distance-based fees affect all travel, not only travel on certain roadway segment, and therefore provide congestion reduction benefits on the surrounding streets without shifting traffic.

2.2.5 Parking Management and Parking Pricing

Parking management and parking pricing are one of the most successful techniques used to reduce vehicle usage inside congested cities. More efficient pricing of on-street parking will make urban driving more expensive but more efficient. Parking management includes several strategies such as parking use regulation, shared parking, and remote parking.

2.2.6 Access Management

Access management is defined as "the process that provides access to land development while simultaneously preserving the flow of traffic on the surrounding system in terms of safety, capacity, and speed" (New York State Department of Transportation, 1996). Arterials should have few conflict points other than at intersections. Direct access for nearby development should not be allowed and extensive on-street parking should be prohibited also. Generally, access management addresses areas like corner clearance, two-way left-turn lanes, median treatments and median openings, frontage and backage roads, dedicated turning lanes, and driveway related issue.

2.2.7 Traffic Signal Spacing and Timing

Traffic signal coordination is one of the most widely used traffic management measures. Adjacent signals are linked on a relative timing set so that the traffic that leaves the first signal arrives when the green is on in the second signal. For a well-designed coordinated signal system, the Manual for Uniform Traffic Control Devices (MUTCD) recommends that signals within 0.5 mile (0.8 km) of each other should be coordinated on major streets.

2.2.8 Freight Transport Management

Although freight trucks represent a relatively small portion of the total traffic, they can make a relatively large contribution to congestion due to their large size and slow acceleration. Different ways can be used to improve freight transportation efficiency by shifting freight to less congested routes, making off-peak hour deliveries, and improving the quality of efficient freight options such as rail and integrated distribution services.

2.2.9 Car-Free Cities and Town Planning

To create zones with controlled private cars access in the cities, car-free cities and town planning techniques are used. Cities with prohibited private cars usage usually have adequate pedestrian streets. Pedestrian streets should have good access to public transport and parking.

2.2.10 Vehicle Restrictions and Pedestrian Improvements

Vehicle restrictions include various strategies that limit vehicles travel at a particular time and/or area. Even if this strategy seems to be a simple method to reduce traffic congestion, it is generally difficult to implement successfully. Pedestrian improvements can be implemented to reduce traffic congestion. Litman (2006) recommended guidelines for creating a successful pedestrian street or zones. This study indicated that pedestrian streets should be located in attractive areas with a pleasant environment, greenery, shade and rain covers. It should be small, short, secure, and clean with good access to public transit and parking.

2.2.11 Reversible Lanes

In a reversible lane, traffic may travel in either direction depending on certain conditions, for example, into a city center during AM peak period and away from it during the PM peak period. This may be controlled by VMS or by movable separation. Figure 2.2 shows a reversible lane.

Figure 2.2: Reversible lane.

More care is required to drive on a reversible lane, since driving on a reverse traffic lane put the drivers in a very close position to oncoming traffic with no barrier between them.

2.2.12 Ramp Metering

A ramp meter is a device, usually a basic traffic light or a two-section signal (red and green only, no yellow) light together with a signal controller that regulates the flow of traffic entering freeways according to the current traffic conditions. It is used at freeway on-ramps to manage the rate of vehicles entering the freeway. Figure 2.3 shows a ramp meter control.

Figure 2.3: Ramp meter control.

2.2.13 Intelligent Transportation Systems

Intelligent transportation systems (ITS) include the application of a wide range of new technologies, including driver information and traffic reporting (via radio, mobile phones, VMS, and traffic cameras), vehicle control, tracking (navigation) systems, transit improvements, and dynamic parking guidance (Litman, 2009). They can provide a variety of transportation improvements, including driver convenience, reduced congestion, increased safety, more competitive transit, and support for pricing incentives. ITS can be seen as tools to help implement demand management policies and support both the decision makers as well as the common users to take decisions regarding transport usage.

2.2.14 Other Measures

Congestion can be reduced by either increasing the road capacity (supply) or by reducing the traffic (demand). Capacity can be increased in a number of ways:

- Intersection Improvements
- Grade Separation
- Road Capacity Expansion
- Incident Detection and Management
- One-Way Streets
- Narrow Vehicles

- Urban Planning and Design
- Flexible Time
- Telework

2.3 Advanced Traveler Information Systems (ATIS)

Advanced ITS techniques are used widely in managing traffic congestion. One of these techniques includes the use of advanced traveler information systems (ATIS). ATIS support motorists in making more accurate decisions to avoid traffic congestion. ATIS have an important effect in reducing congestion, accidents, fuel consumption, and pollution through emission reduction. Static or dynamic traffic information can be provided by these systems. Static systems provide information on long-term events such as construction activities and maintenance, toll payment options, and mass transit schedules.

Dynamic systems provide instantaneous information on streets conditions updated in response to the current conditions. These conditions include traffic congestion, incidents occurrence, available alternate routes, transit bus schedules and the parking spaces availability. Figure 2.4 presents the generic ATIS system showing how information on current conditions is gathered and dispersed through different control devices (Schiesel and Demetsky, 2000).

In general, ATIS have several benefits. It can reduce travel time and crash risk especially at congested roads, reduce traveler stress and distractions on unfamiliar routes, and decrease fuel consumption and air pollution. ATIS performance can be evaluated using several measures of effectiveness (MOEs). Some of these measures are operational like volume to capacity ratio, travel time, delay, average speed, vehicle miles of travel, level of service, and number of stops. Other measures are economics like saving delay, fuel, accidents cost, and environmental like emissions reduction.

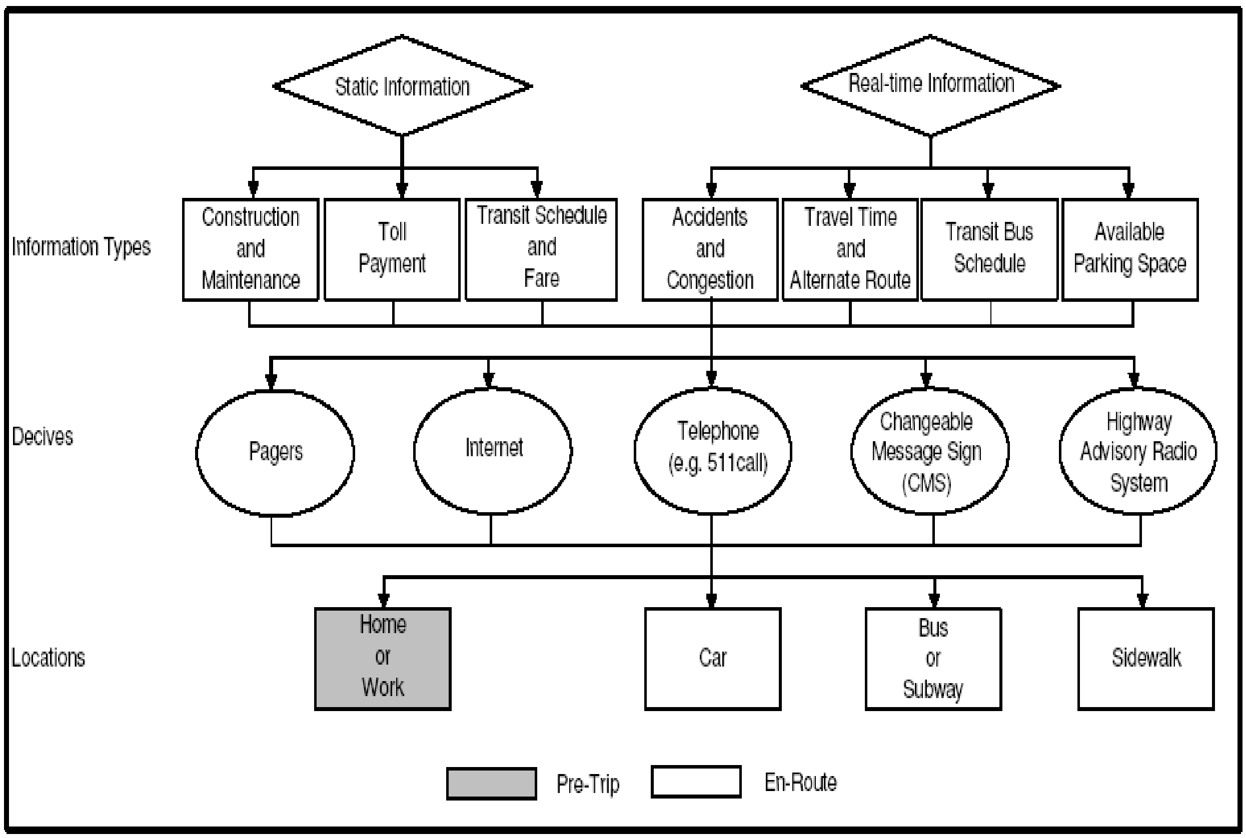

Figure 2.4: Generic ATIS system (Schiesel and Demetsky, 2000).

2.4 Variable Message Signs

One of the most fundamental technologies available for displaying traffic-related information from the roadside is the Variable Message Signs (VMS). VMS is also known as Changeable Message Signs (CMS) or Dynamic Message Signs (DMS), and in the UK it is known as matrix signs. VMS are programmable traffic control devices that can usually display any combination of characters to present messages to the motorists. It is also defined as electronic traffic signs used on roads to alert motorists of incidents or obstructions such as traffic congestion, accidents or roadworks.

VMS is defined as a sign for the purpose of displaying one of a number of messages that may be changed or switched on or off as required (CEN, 2005). The beginning of VMS started in the early 1960s in the United States when it was only capable of displaying a small number of messages. With computer technology, VMS now has the capacity to display a nearly unlimited number of messages.

2.4.1 VMS Types

There are two different types of VMS used on the roadways: a permanent VMS which is used on high density roadways to advise the drivers of congestion locations, warn them of accident or incident conditions, or display speed limits or lane restrictions, and a portable VMS which is usually used for non-recurring congestion caused by temporary capacity reductions from construction, maintenance, or severe weather conditions. Portable VMS is much smaller than permanent VMS. The technologies used for VMS are either fiber-optic signs or electromechanical signs.

VMS messages are classified into two main categories from the perspective of their usage to the drivers: passive and active. A passive message provides descriptive information of the problem the driver may encounter. This information can include the type of incident, its location, and expected delay. Passive information may be further classified as qualitative or quantitative. Qualitative information refers to the problem generically (e.g., accident, work zone, and congestion) whereas quantitative information focuses on specifics (expected delay, location, etc.). An active message provides the driver with explicit route guidance such as the best available alternate route for avoiding the bottleneck (Lim, 2005).

2.4.2 VMS Content and Format

To be efficient, VMS format should be done to reduce the time required to understand the meaning of the message. If the information in the VMS is presented in a non-standard format, it will increase the time required to understand the message and may confuse the drivers leading them to make accidents. Section 2A.07 of MUTCD states that "except for safety or transportation related messages, changeable message signs should not be used to display information other than regulatory, warning, and guidance information related to traffic control." Guidelines on the design of VMS contained in MUTCD, suggest the following message elements in the sequence shown: What is the problem?, Where is the problem?, and What is the effect?

The recommended configuration of a VMS board is shown in Figure 2.5, examples of VMS displaying messages are shown in Figure 2.6.

Figure 2.5: VMS configuration.

Figure 2.6: VMS advising drivers to reduce speed.

The guidelines on the amount of information that should be available in any VMS were presented by Florida Department of Transportation (2008) as: maximum of eight words at a speed of 55 mph, maximum of seven words at a speed of 65 mph, and maximum of six words at a speed of 75 mph. It is important to consider how the words should be arranged in the message since it affects the time for travelers to comprehend the message and react. Sometimes messages are too long to be displayed in one frame; therefore, they need to be shown in two frames.

VMS messages for incidents including emergencies, construction or maintenance closures have basically three main components: problem, location of the problem, and recommended driver action.

Messages should be displayed at exposure rates of one sec/word or two sec/unit of information where a unit of information is a data item in a message that a motorist could use to make a decision.

Viewing time is associated with message viewing distance and there may not always be enough viewing time for travelers to read a VMS message. Some of the factors that affect viewing time are: speed of travel, placement of the VMS (over travel lanes versus side of the road), lighting conditions, roadway geometrics, environmental conditions, and number of trucks (Florida Department of Transportation, 2008).

2.4.3 VMS Effect and Usage

VMS signs are intended to provide en-route real-time information to the drivers and alert them of sudden or unexpected changes in traffic conditions to reduce congestion, enhance safety, and improve system performance. In urban areas, VMS are used within parking guidance and information systems to guide the drivers on the available car parking spaces. The message displayed may be in the form of either simply an information message or as an advisory message. VMS can be used as any of the three sign categories: advisory, guide, or regulatory signs. Such messages can contain words, numbers or symbols (Lim, 2005).

Lim (2005) also mentioned that the most important conditions for the drivers to catch the messages on road signs and to change their behavior according to this information are the legibility of the road sign and understanding of the message, the location of VMS, the relevance of the road sign, and the credibility of the message (effects on driver behavior).

Based on Sara and Gabriel (2007), an article evaluating bilingual signs of different techniques was published by Jamson (2004). Sometimes the message was in English, sometimes in Welsh, and sometimes both in English and Welsh in various combinations. Reading times of the participants were measured according to these conditions. It was found that for bilingual messages with only two lines, one for each language, there was no reading time difference compared to one-line monolingual signs. However, for four-line bilingual messages, the reading time was significantly increased. If the lines of the signs were grouped after the language, not by content, the reading time was significantly faster.

A study conducted in Rhode Island aimed to provide the public with a more efficient and safer daily travel environment. The highway authority in Rhode Island (RI) has deployed a number of state-of-the-art VMS to communicate instantaneous traffic information and travel advice to drivers since the late 2002. The approximate sign dimensions are 8534 mm wide by 2388 mm high with a matrix of 120 × 27 LED pixels. Each LED pixel matrix is a 9 × 5 display module and has a cluster of five red and three green closely spaced, discrete LEDs. When all the red and green LEDs in the cluster are lit up, amber message can be displayed. The study also considered some demographic differences among the drivers' age, gender, and native language. It is important to know whether these factors: affect a driver's ability to properly understand a message, affect the amount of time it takes a driver to read and comprehend a message, and influence the importance that a driver places on a message (Wang et al., 2006).

There are two important things to consider when using a VMS. These are the driver expectations and the credibility of the information. With driver expectations, it means that the system has to work and show correct messages because the drivers expect to get updated information. This is a necessity that must be provided to the drivers. Credibility means that the information has to be relevant and rational to be obeyed. Furthermore, Sara and Gabriel (2007) said the following:

- Less information or no information at all is better than an ill-founded message. Not to show any message is better than guessing.
- Never show messages that the motorists do not find rational. Regulating instructions about road choice should only be given if well motivated.
- Never encourage motorists to deviate from the ordinary route in order to balance demand with accessible capacity in rush hours, unless this favors the individual driver. This may produce great credibility problems.
- The recommended alternate road must result in an evident improvement (saving of time) of the journey.

Based on Sara and Gabriel (2007), the compliance of a VMS when it comes to alternate road choice depends mainly on the following factors:

- How many have read the message on the VMS?
- How many understood the message on the VMS?
- How many trusted the message on the VMS?
- For how many drivers is it relevant to use the alternative route?
- How accessible is the regular road perceived?
- How accessible is the alternate road perceived?

- How well do the motorists know the alternate road?

Florida Department of Transportation (2008) mentioned the following benefits of using VMS as a way to provide en-route traveler information to motorists:

a) Improve safety

b) Reduce trip time

c) Save costs

d) Help motorists make more educated decisions regarding route choice

e) Reduce fuel consumption

f) Reduce emissions

g) Improve the public perception of the usefulness of VMS

h) Save lives through emergency response, and

i) Reduce secondary collisions (Florida Department of Transportation, 2008).

To obtain the full benefit of VMS, it is critical that messages are quickly and easily comprehended. It is known that messages that are too long or confusing may cause driver overload, distraction and/or anomalous reactions like drivers slowing down abruptly to read and/or decipher messages. The project of Chang and Russell (2010) investigated how well the drivers in New Zealand understand abbreviations and phrases that have been used in VMS.

VMS can be used to manage traffic by displaying the three types of messages as follows:

1- Early warning messages: give motorists advanced notice of slow traffic and queuing ahead and are effective in reducing secondary crashes. When used in freeway work zones, early warning messages also give notice of new detours, changes in detour route, changes in lane patterns, special speed control measures, etc.

2- Advisory messages: provide motorists with useful information about a specific problem along their route. This information allows motorists to change their speed or path in advance of the problem area, or may encourage them to voluntarily take an alternative route to their destination.

3- Alternative route messages: influence motorists to travel to their chosen destination by using different routes than originally intended. The alternative route is one designated by the transportation agency. In cases where the freeway is physically closed as a result of construction, crash, or natural disaster, the motorists are notified that an alternative route must be used (Barnard et al., 2011).

2.4.4 Drivers Route Choice Behavior

A telephone survey was conducted in Los Angeles to evaluate drivers route diversion behavior through different types of traffic information used. The study indicated that about 70% of the commuters would divert to alternative route if adequate traffic information were provided to them. About 80% of the commuters indicated that the available traffic information in the area was not enough. Also they indicated that the use of advanced traffic information systems could help them in route selection (Shirazi et al., 1988).

In another study, interviews were conducted on commuters in Seattle, Washington to assess their decisions on route or mode choice due to pre-trip traffic information. This study indicated that only one-third of the commuters use pre-departure traffic information in their route choice. The study also indicated that about 66% of the commuters reported that they rarely change their original route, and around 90% of them rarely change their mode. About 78% of the commuters reported that their stress level increased during the use of alternative route. Commuters indicated that instantaneous en-route traffic information and observed traffic queue affect their decision to change route (Wenger et al., 1990).

Another survey aimed to enumerate the factors affecting drivers route choice in Massachusetts. This survey indicated that drivers habits, time of the day and stopped time are important factors affecting route selection. About 62% of the drivers indicated that they altered their route due to their own observation, while only 12% altered due to radio information, and 26% altered for other different reasons (Polydoropoulou et al., 1994).

In a survey of users of the smart service in Seattle, 93% of the respondents agreed with the statement ‘using traffic information on the web has helped me to save time’. Results of a similar survey in Washington D.C. found that more than 85% of ATIS users were confident that they were saving time (Richards and McDonald, 2007).

2.5 VMS Evaluation Studies

Several international previous studies were conducted to measure the impact of variable message signs by using the field study methods or by collecting data based on survey questionnaires (field, mail, telephone, etc.).

2.5.1 VMS Understanding Studies

A study was conducted to evaluate and develop abbreviations in VMS using a human factors laboratory in New Jersey. This study indicated that there were regional differences with respect to driver understanding of some of the abbreviations. For example, 88% and 85% of the drivers tested in northern New Jersey understood the abbreviations EXP CLSD and LOC LNS for “Express Closed” and “Local Lanes”, respectively, whereas less than 70% of the drivers studied in southern New Jersey understood these two abbreviations. Also, the abbreviations for some of the facilities/structures were generally understood by a very high percentage of drivers who live near the facility/structure. For example, the abbreviations studied for “Mount Tabor” and “Sandy Hook National Park” which are located in north New Jersey were understood by 88% of the drivers tested in that part of the state. In contrast, only 58% and 65% of the drivers tested in south New Jersey understood the abbreviations (Hustad and Dudek, 1999).

It is critical to post sign messages that can be quickly and clearly understood by motorists, especially in high-volume traffic and construction zones. Properly worded and formatted sign messages could spell the difference between comprehension and confusion. A human factors study was carried out to help enhance ways to communicate with highway motorists through VMS. Two approaches were employed in this study. First, a questionnaire survey was developed to collect motorists' preferences regarding various message display factors. Second, a series of lab driving simulation experiments were set up to assess the effects of these factors and their interactions on motorists' comprehension of VMS messages. Results of the study suggested that static, one-framed messages with more specific wording and no abbreviations were preferred. Amber or green or a green-amber combination was the most favored colors. Results also indicated that there were differences related to native language and age, but there was no significant difference in gender (Yang et al., 2004).

Another study aimed to test VMS characteristics and evaluate drivers' knowledge and response to VMS was conducted in Rhode Island. The study employed three approaches in the evaluation: questionnaire surveys, lab simulation experiments, and field studies. From the questionnaires, the drivers suggested one frame with minimum flashing messages with no abbreviations, to be displayed in either yellow or mixed yellow with green. The lab experiments indicated that such suggestions from the drivers demanded less response time. The results were also supported by the field studies. The study also tested the effect of age, gender, and native language. The results indicated that there was no difference in the drivers' suggestions regarding characteristics and response to VMS in gender and native language, while young drivers took less response time with high accuracy than the old drivers (Wang et al., 2006).

2.5.2 VMS Survey Studies Evaluation

A driver questionnaire was conducted to evaluate the impact of VMS available on a freeway in Wisconsin. The results of this study showed that approximately 72% of the respondents indicated that they change their route due to traffic information displayed in VMS during non-winter months (April-November). Around 68% of them indicated that they change their route in winter months (December-March) (University of Wisconsin, 2001).

Another survey aimed to explore the drivers' response to different VMS messages in London through two approaches. In the first approach, the effect of different VMS messages on drivers' diversion rate was evaluated using questionnaire survey. The respondents indicated that VMS is a useful control tool, and they support the use of VMS in the future. In the other approach, a survey of drivers' actual responses to a message activation showed that only one-third of the drivers saw the information presented to them and few of these drivers diverted, although many found the information useful. This number represents only one-fifth of the number of drivers expected to divert from the results of the questionnaire (Chatterjee et al., 2002).

In another survey in Wisconsin, the road users' opinion on travel conditions and their knowledge about VMS were evaluated. The main findings of this survey showed that about 40% of the drivers indicated that they are familiar with VMS technology. Around 82% of them indicated that if they knew that there was heavy congestion on the road, then they will change their trip time. In addition to that, most of the drivers reported that they will alter their route if VMS displayed messages related to road work activities, accident or congestion occurrence. They indicated that VMS enhances safety, improve travel efficiency, and reduce driving time. Also, the drivers indicated that the main factor that prohibits them from altering their route is that they do not know whether the new route would be faster (Ran et al., 2004).

The project of Wang et al. (2006) listed several VMS survey studies. In the Washington, D.C. area, a drivers survey was conducted to assess their previous response to VMS. The results indicated that about half of the participants usually responded to VMS while 38% occasionally responded to VMS. In Amsterdam, based on survey study, more than 70% of the drivers indicated that they were sometimes influenced by VMS information. In Paris, a survey conducted found that 70% of the drivers believed that VMS are useful. The study indicated that young drivers are less prone to comply with VMS advice.

A study aimed to assess the road users' response to traffic information displayed on VMS through different types of survey (an on-site survey, a mail-back survey and an internet-based survey). From the internet-based survey, it was found that 47% of the respondents stated that they would divert to an alternate route, while it reached 75% from mail-back survey, and 84% from on-site survey. On the other hand, the internet-based survey found that 97% of the respondents were familiar with at least one alternate route besides the studied expressway, 90% from the mail-back survey, and 65% from on-site survey. They also indicated a high correlation between VMS content and drivers' response. The results indicated that the use of more than one type of these methods produce more accurate data (Peeta and Ramos, 2006).

A study by Richards and McDonald (2007) listed several VMS survey studies. In Glasgow, 47% of the questionnaire respondents reported that they diverted as a result of VMS. In Paris, about one-third said they often changed route and a quarter said that they would not divert under any circumstances. In Toulouse, 7% said they always followed the recommended directions, 30% said sometimes and 63% said never. In Turin, about 20% of all the drivers or nearly 90% of those drivers who had seen the VMS followed the directional advice.

User acceptance of VMS was studied in an urban road network in Southampton, UK. The public perceived effectiveness and usefulness of these signs through the use of questionnaire surveys and travel diaries was investigated. 365 commuters regularly driving into Southampton from the outskirts of the city completed a travel diary for a 5-day period as well as a general questionnaire, and 660 infrequent travelers to Southampton completed the general questionnaire. The study showed that it is difficult to capture a meaningful sample size of the respondents passing an 'active' VMS in a real-life incident scenario. Less than 1% of the commuter sample stated that they had diverted to an alternative route during the travel diary week as a result of VMS information, although this did not correspond to 53% of those 45 drivers originally intending to travel past the incident location. The results showed that the VMS messages were well understood and legible, and also indicated that a default VMS message reporting no problems in the network can indirectly affect a driver's route choice (Richards and McDonald, 2007).

A study on comprehension of VMS was carried out in Finland, England and Italy. The study investigated the drivers understanding of the factors that control the VMS display.

All the participants were 25 to 35 years old and had a driver's license. It was concluded that gender and driving experience did not influence the results, but country influenced the results (Sara and Gabriel, 2007).

A study in Trondheim investigated the impact of six VMS using simulations and user surveys. This study indicated that most drivers in the city consider VMS as useful, while a few altered their route as a result of the information displayed on VMS (Høye et al., 2011).

2.5.3 VMS Field Studies Evaluation

A survey aimed to evaluate the road users' response to 350 VMS on the ring motorway in Paris. The study concluded that from zero to 40% of the road users normally choose an alternative route after being aware of the information through VMS. Also, the study indicated that about 80% of the drivers preferred to be informed of travel time rather than queue lengths (Kronborg, 2001).

To assess the drivers' response to VMS, trials in several locations between two cities in Sweden were conducted. A minimum of 6% of the drivers responded to VMS suggesting alternative routes to avoid congestion in one location, while the maximum response reached 40% in other locations. It was found that when 30% of the drivers responded to the VMS signs, a maximum delay was controlled. At peak times, a diversion of 10% may be adequate for traffic relief (Davidsson and Taylor, 2003).

A study was aimed at developing VMS knowledge in Europe. An investigation was made in order to find out whether the compliance was higher for a speed limit sign displayed with another sign explaining why the speed limit was set. It was concluded that speed limit signs were most often obeyed, but the display of extra information justifying the speed limit led to even higher compliance, and most drivers correctly interpreted the VMS in 1.0-2.5 sec (Sara and Gabriel, 2007).

The study by Richards and McDonald (2007) indicated that from 0-3% of the drivers diverted in response to a VMS message relating to roadwork in London, 27-40% for accident messages, and 5-25% for congestion messages.

In a field study in Norway, vehicles speed, braking behavior, and route selection were compared before and after the activation of VMS which displayed a road closure with recommended alternative route. The results indicated a high response to the VMS. The percentage of vehicles that diverted to alternative route in accordance with VMS increased by 23%. In addition to that, a reduction of 6 km/hr on average speed was measured when VMS displayed the message. Also, a considerable amount of vehicles braked while approaching the VMS. Erke et al. (2007) indicated that the proportion of drivers actually changing route choice varies considerably, and it is seldom over 40%.

Another study was carried out on a large scale test on speed limit and warning variable signs in several places in England. Speed data before and after the installation of VMS was collected, and accident data and public opinions were investigated. It was found that warning signs reduced mean speeds by up to 11 km/h (7 mph). In addition, the percentage of vehicles exceeding the speed limit was reduced. The report concluded that drivers can be influenced by VMS in reducing speed. Vehicle-activated signs appear to be effective in reducing speeds, especially in reducing the number of drivers exceeding the speed limit. There was no proof found that drivers would become less responsive to the signs over time (Sara and Gabriel, 2007).

Another study aimed to evaluate the VMS impact in rural areas in southeast Missouri using drivers surveys and field studies. About 94% of the drivers surveyed indicated that they consider the information provided by the VMS. A statistical significant reduction in average speed of 3.64 mph was observed (Edara et al., 2012).

2.6 VMS Modeling Studies

A survey aimed to explore the drivers' response to different VMS messages in London. The survey data that was analyzed through the development of a binomial distribution model related the probability of diversion to driver and message characteristics, together with logit function which provides the transformation to a linear model. The results indicated that some variables are statistically significant at the 5% confidence level, such as cause of the problem (accident, congestion, and roadworks), problem location and severity of the problem (Chatterjee et al., 2002).

A model combining the data collected from the on-site, mail-back and internet-based surveys was developed. Binary logit models were used in this study because the choice set of each respondent consists of only two alternatives, divert or not divert. The difference in the utility functions is related to relevant variables representing the drivers' socioeconomic characteristics and the VMS message types provided. The resultant model indicates that males are more likely to divert to an alternate route under an incident situation. Younger drivers are more inclined to divert than older drivers when all other conditions are identical. Regular drivers in the study region are more likely to divert. Well-educated drivers are more likely to divert as reflected by the positive sign of this variable (Peeta and Ramos, 2006).

To investigate the correlation between lab experiments and field studies, a simple linear regression analysis was conducted with the mean response times obtained from the field study as the dependent variables. The regression equation was found as:

$$\text{Field Study} = -28.1 + 1.70 \text{ Lab Experiment}$$

ANOVA results showed that the regression model had a moderately strong adjusted R^2 value = 63% and was significant at 0.05 significance level, indicating a good predicting power (Wang et al., 2006).

A study of the effect of different message contents was conducted on drivers’ response to VMS at Borman Expressway. The main objective of this research was to build driver behavior models that predict the diversion probability of an individual driver under a specific VMS message content. Binary logit models were developed for drivers’ diversion decisions consisting of only two alternatives – divert or not divert. The analysis suggested that the content in terms of the level of details of relevant information significantly affects the drivers’ willingness to divert. Other significant factors include network spatial knowledge, confidence in the displayed information, and socioeconomic characteristics such as gender (males are more likely to divert than females under similar conditions), and age (younger drivers are more likely to divert compared to older drivers), and educational level (well-educated individuals exhibit greater compliance with VMS compared to less educated drivers) (Peeta et al., 2006).

2.7 Simulation Softwares

In analyzing the effect of VMS field studies, a simulation software is needed. One of the powerful simulation softwares that is used to evaluate MOEs is TRANSYT-7F. On the other hand, a flexible simulation software is needed to model the current traffic situation (with some having unusual characteristics). It was found that Arena simulation software can deal with such issues.

2.7.1 TRANSYT-7F

TRANSYT-7F is an off-line macroscopic deterministic simulation and optimization model that simulates traffic as cycle flow profiles, traces the flow of cycle flow profiles from link to link throughout the network, and makes systematic changes to the offset, phase split, and cycle length of the traffic signals. It also simulates the associated traffic conditions to estimate a corresponding performance index. This index is composed of vehicle delay and number of vehicle stops.

TRANSYT can be used to model of existing conditions and future conditions for mixed signaled and unsignaled networks at time-varying traffic conditions. It can optimize signal timing with accurate offsets phases and split optimization, in addition to some other various capabilities.

Input data required for this software involves: Dividing roads and lanes into either links with shared signals and shared traffic movements. Further dividing the flows from different sources within a single section of road space using shared link. Then, assigning a saturation flow to each link (or lane), indicating the maximum flow of traffic over the stop line during the green time. Finally, entering the signal timings that apply to each link (or traffic stream).

The output from this software include a set of measures for each link, such as delay, number of stops, fuel consumption, degree of saturation, and the performance index (indicating the cost of the stoppages and delays within the network), and for the overall network, such as total distance travelled, mean journey speed, fuel consumption, and performance index.

2.7.2 ARENA

Arena is considered as the preeminent solution for better decisions with simulation. In this software, it is easy to analyze an existing situation or predict the future conditions with confidence. Arena is an easy-to-use, powerful tool that allows the user to create and run experiments on models of any systems. This software provides the maximum flexibility and breadth of application coverage to model any desired level of detail and complexity. Arena provides an intuitive, flowchart-style environment for building an "as is" model of the process by adding real-world data.

Building a model with Arena is conducted using modeling shapes called modules, from which to define the process. There are two types of modules on a panel: Flowchart modules and Data modules. Changes can be made to the model to capture the possible scenarios to be investigated, and compare the results to find the best "to be" solution.

2.8 VMS in Saudi Arabia

Traffic status in Saudi Arabia has special characteristics. There is a considerable amount of young drivers who have special behaviors making them more prone to violate traffic regulations. There are large numbers of expatriate drivers with serious communication problems, and there are limited mass transit services.

Recently, VMS technique was introduced in few locations in Saudi Arabian highways. Drivers' response to VMS instantaneous traffic messages is not known yet. Currently, these VMS display general static information messages not directly related to instantaneous traffic situation. The aim of such effort is merely to get the drivers acquainted with the VMS technology (to familiarize local drivers with this technology) and to test their reliability under local conditions.

2.9 Summary

From the literature review, it can be noticed that there is a lot of congestion management techniques that can be applied on the Kingdom's streets. Some of them can be efficiently used with the availability of enforcement, while some are difficult to be applied. One of these techniques which is related to the use of intelligent transportation systems is the variable message signs.

As shown from the literature, these signs can be used as early warning, advisory, and/or alternative route messages, and should consider the driver expectations and the credibility of the information (relevant and rational to be obeyed). Also, it is noticed that most of the drivers preferred to be informed of travel time rather than queue lengths on the VMS.

From the previous studies, either surveys methods or field experiments were conducted to evaluate the drivers' response to VMS. It was found by field experiments that about 0-40% of the drivers changed their route choice in accordance with the recommended route in the VMS. There are several possible explanations for these inconsistent results in the previous research, as it did not consider all the factors which potentially affect the drivers' route diversion. Drivers' attitudes are not consistent at all times of the day. Diversion behavior is different for different trip purposes, and drivers' route diversion varies with familiarity with the location. The effect of VMS may also differ based on geographic locations.

According to studies based on survey, approximately 70% of the respondents reported adjusting their travel routes based on the travel time or traffic information provided by the VMS. Such studies indicated that there were differences related to native language, age and type of vehicle, and there was no significant difference in the gender.

It is noticed from some survey studies that participants consider the use of VMS as an important need to reduce traffic congestion, and these signs are useful to report weather and traffic conditions.

It is also clear from the literature that most drivers decide their driving route before departure (pre-route choice) and have one regular route, especially for their commute trips. Usually, drivers look for faster and shorter route. It was concluded from the literature that drivers' characteristics are not the only factor that affects diversion or change of route but it is also affected by factors such as the trip purpose, geographic and network location, traffic conditions (congestion and delay), familiarity with the location, and severe weather conditions.

Some of the research concluded that VMS do not have a significant effect on the drivers' route diversion behavior, while other research indicated otherwise. Also, the literature indicated that whether the drivers can observe or cannot observe the congestion queue from the place where they are located might have a different effect in choosing to change their route. Studies also indicated that the location of the incident and the message content are important factors influencing the probability of diversion.

CHAPTER 3

VMS EVALUATION THROUGH DRIVERS INTERVIEWS

3.1 Introduction

Interviews were conducted to explore the drivers' knowledge and responses to the information when disseminated via VMS. The interviews were done with samples of drivers selected randomly from the area in the vicinity of the studied arterial. Drivers in retail stores, companies, and shopping malls along the studied arterial were interviewed. It is important to mention that the interviews were designed both in Arabic and English, since the messages in the VMS in most previous studies were displayed only in native and/or English language.

3.2 Survey Design

The main objective of the interviews was to evaluate the response of the regular commuters to VMS messages and to assess the response of those individuals who drove on this street less frequently (visiting or shopping) to the VMS messages.

After identifying the key factors that influenced the drivers' response decisions to VMS (especially route diversion), the questionnaire was designed as follows (see Appendix A):

In the first part of the interview, the drivers were asked about their personal characteristics including nationality, age, educational level, driving experience, native language, ability to read basic Arabic or English, and the type of vehicle they drive.

In the second part, the drivers were asked to assess the anticipated benefits of VMS and their familiarity with traffic information conveyed through VMS messages. The responses to these questions were measured on a subjective scale ranging between highly helpful and not helpful. These questions covered the following issues:

a) The importance of notifying the drivers about highway travel condition

b) The merits of providing traffic information in VMS

c) Familiarity with VMS

d) Their opinion on the effectiveness of VMS in reducing traffic accidents, driving stress, and saving driving time

e) Drivers' confidence on VMS messages

f) Their opinion on the usefulness of VMS in displaying messages concerning accidents occurrence, weather conditions, roadwork activities, traffic congestion occurrence, special events, and alternative roads.

Finally, the last part of the interview explored the drivers' responses to VMS requesting them to change their route due to some traffic circumstances such as accidents occurrence, adverse weather conditions, roadwork activities, traffic congestion occurrence, and special events like fairs and sporting events. Responses were measured on a subjective scale of four categories, namely: never abided with VMS request, rarely abided with VMS request, usually abided with VMS request, and always abided with VMS request.

3.3 Sample Size

The interviews were done with samples of drivers selected randomly through from drivers using the studied arterial. Drivers in retail stores, companies, and shopping malls along the studied arterial were also interviewed.

The following equation was used to estimate the number of interviewed drivers who will use an alternative route if VMS is used since standard deviation is not known:

$$N = p * q * (Z_{\alpha/2}/d)^2$$

where:

p : proportion of interviewed drivers who responded positively to VMS.

q : proportion of interviewed drivers who responded negatively to VMS (q=(1−p).

d : permitted error.

$Z_{\alpha/2}$: Z value related to the target confidence level.

A pilot study has been conducted to have an estimate of the proportion of drivers who responded to VMS to change their route (p). About 50 drivers were interviewed and 70% of them responded positively that they will change their route. To have the largest sample size, p was considered as 0.5; this will always give a more conservative sample size.

Confidence level was considered as 90%, so $Z_{\alpha/2}$ equal to 1.645 and permitted error (d) was considered as ±0.1. The estimated sample size of the experiment is 68 drivers. And since the drivers were interviewed also on 25 items each of which has 4 possible responds, the sample size was generously increased to 250 drivers.

3.4 Characteristics of the Interviewed Population

From the first part of the interview, it was observed that 49% of the sample were Saudi, 31% were Arabs and 20% were from nationalities other than Arabs whose mother language is not Arabic, as shown in Figure 3.1.

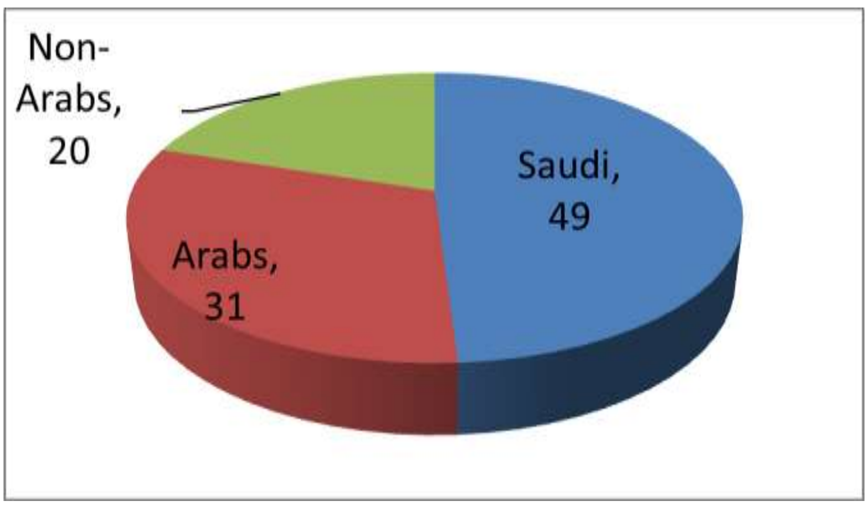

Figure 3.1: Nationality distribution in the sample.

The above percentage of interviewed population approximately represents the actual population in the community. The age of the interviewed drivers was distributed as shown in Table 3.1.

Table 3.1: Age distribution in the sample.

Age interval (years)	**Number**	**Percentage %**
Less than 20	44	18
20-less than 30	142	56
30-less than 40	42	17
40 or more	22	9
Sum	250	100

From Table 3.1 above, it clearly appears that around 74% of the interviewed drivers were less than 30 years old. This represents the high percentage of young drivers in the study area.

Driving experience was found to be approximately equally distributed in the total sample. 31% of the drivers have less than 3 years of driving experience, 38% have driving experience from 3 to 6 years, and 31% of them have driving experience of 6 years or more, as shown in Figure 3.2. About 47% of the drivers have educational level below college, while 53% of them have college or more education. About 88% of the drivers can read basic Arabic or English words, and about 89% of them are familiar with the surrounding routes.

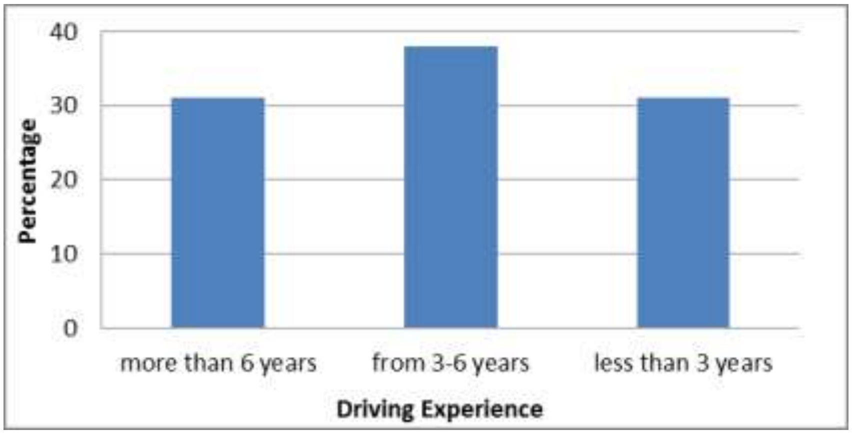

Figure 3.2: Driving experience distribution in the sample.

From the second part of the interview, about 85% of the drivers acknowledged that it is important to notify the drivers about highway travel conditions through radio or electronic message signs. About 15% of the drivers never heard about VMS technique, while 21% are familiar with this technology but never experienced it while driving. 41% of them were occasionally exposed to it in other countries (two to three times in their driving history), and 23% are very familiar since they are driving in cities that utilized VMS technology, as shown in Figure 3.3.

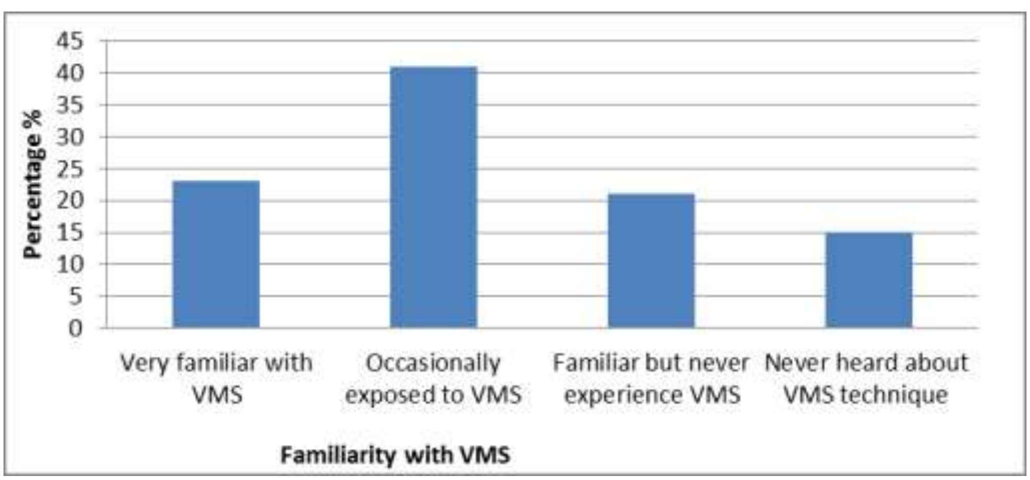

Figure 3.3: Familiarity with VMS in the sample.

Figure 3.3 indicates that the respondents in this study were somewhat familiar with VMS technology. About 78% of the drivers indicated that VMS improves safety, reduces accidents, reduces driving stresses, and saves driving time. 82% of the interviewed drivers indicated that it is useful to display traffic and travel time information on VMS. About 43% of the drivers highly trust the information provided in VMS, 41% trust it to some degree, 6% do not trust and 10% had no opinion on this issue, as shown in Figure 3.4.

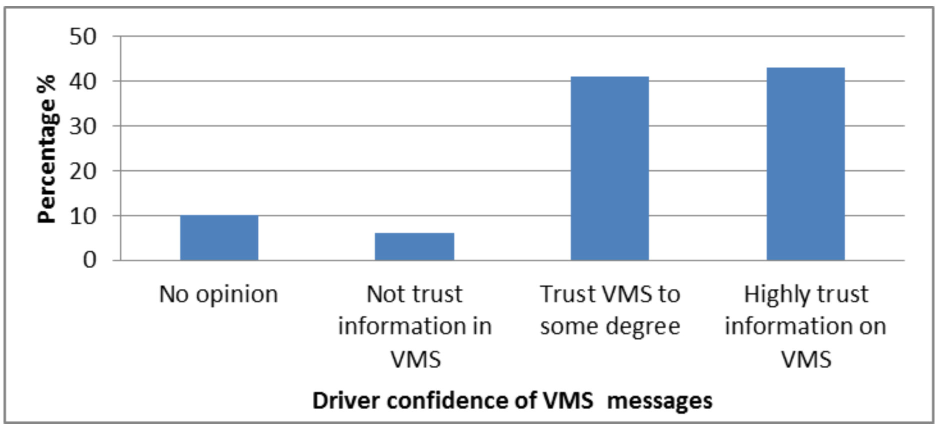

Figure 3.4: Drivers confidence on VMS messages.

Figure 3.4 above indicates that around 84% of the interviewed drivers indicated that they trust the VMS information. From the last part of the interview, the percentage of positive response seems to range from 65% to 84% depending on the nature of the event. Observations about drivers' reaction to VMS are summarized in Table 3.2.

Table 3.2: Percent of drivers who will alter their route in response to VMS.

VMS display	Never change route		Rarely change route		Usually change route		Always change route		Sum
	No.	%	No.	%	No.	%	No.	%	
Instantaneous traffic condition messages	15	6	40	16	128	51	67	27	**250**
Accident occurrence	10	4	30	12	93	37	117	47	250
Roadwork activities	8	3	37	15	95	38	110	44	250
Traffic congestion	10	4	35	14	93	37	112	45	250
Weather condition	13	5	60	24	102	41	75	30	250
Special events	32	13	55	22	70	28	93	37	250

Table 3.2 was rearranged by consolidating the first two columns (never and rarely change route) into one column under the title "Negative response to VMS". Similarly, the third and fourth columns (usually and always change route) from Table 3.2 were consolidated into one column as "Positive response to VMS". Table 3.3 gives a more holistic picture of the drivers' response to VMS.

Table 3.3: Drivers' response to route change.

VMS display	Negative Response		Positive Response		Sum
	No.	%	No.	%	
Instantaneous traffic condition messages	55	22	195	78	250
Accident occurrence	40	16	210	84	250
Roadwork activities	45	18	205	82	250
Traffic congestion	45	18	205	82	250
Weather condition	73	29	177	71	250
Special events	87	35	163	65	250

In the last question in the questionnaire, the drivers were asked about the reasons they would choose in not adjusting their travel route. The results indicated that 26% are afraid that they will get lost if they alter their original route, while 35% indicated that they do not know the alternate routes, 16% do not feel safe driving in unfamiliar roads, 10% do not trust the information provided in the signs, and 13% have no opinion, as shown in Figure 3.5.

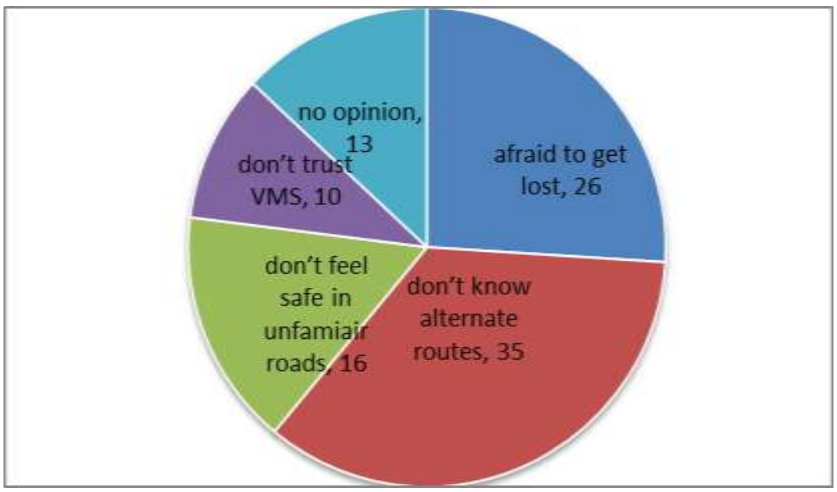

Figure 3.5: Drivers reasons not to adjust route.

3.5 Statistical Analysis Results

The collected data was also statistically analyzed through contingency tables and chi-square test using Minitab software. This study relied on chi-square test because of the nature of the data which is not dependent on any statistical assumption like normality. Chi-square test is also suitable for categorical data. The effect of certain drivers' personal characteristics on their response to VMS was also statistically tested at 90% confidence level, using contingency tables and chi-square test. The collected data was statistically analyzed by setting several hypotheses. A hypothesis was set for the relationship between drivers' personal characteristics and the parameters (related to drivers familiarity and response to VMS) being studied, which is:

H_0 : there is no relationship between drivers' personal characteristics and the parameters being studied.

H_1 : there is a relationship between drivers' personal characteristics and the parameters being studied.

These hypotheses are rejected if the calculated chi-square value is greater than the tabulated value. The difference is considered to be significant if the P-value at chi-square table is less than 0.1 (90% confidence level). To find out which variable has the biggest contribution in the difference, the chi-square for each variable was compared with the tabulated value (2.7) in bold and underlined font in the tables.

3.5.1 Evaluation of VMS Displayed Messages

The collected data was also statistically analyzed through contingency tables and chi-square test to examine the relation between the drivers' response and VMS displayed messages, as shown in Table 3.4.

Table 3.4: Relation of VMS display with drivers' response.

VMS display/ Adjustment		Never	Rarely	Usually	Always
Accident occurrence	Observed	10	30	93	117
	Expected	14.6	43.4	90.6	101.4
	Chi-square	1.5	**4.1**	0.06	2.4
Roadwork activities	Observed	8	37	95	110
	Expected	14.6	43.4	90.6	101.4
	Chi-square	**3.0**	0.9	0.2	0.7
Traffic congestion	Observed	10	35	93	112
	Expected	14.6	43.4	90.6	101.4
	Chi-square	1.4	1.6	0.06	1.1
Weather condition	Observed	13	60	102	75
	Expected	14.6	43.4	90.6	101.4
	Chi-square	0.2	**6.3**	1.4	**6.8**
Special events	Observed	32	55	70	93
	Expected	14.6	43.4	90.6	101.4
	Chi-square	**20.7**	**3.1**	**4.7**	0.7

Chi-Sq = 61.217, DF = 12, P-Value = 0.00

Table 3.4 was rearranged by consolidating the first two columns (never and rarely change route) into one column under the title "Negative response to VMS". Similarly, the third and fourth columns (usually and always change route) from Table 3.4 were consolidated into one column as "Positive response to VMS" as shown in Table 3.5.

Table 3.5: Relation of VMS display with drivers' response.

VMS display / Adjustment		Negative response	Positive response
Accident occurrence	Observed	40	210
	Expected	58.0	192.0
	Chi-square	**5.6**	1.7
Roadwork activities	Observed	45	205
	Expected	58.0	192.0
	Chi-square	**2.9**	0.9
Traffic congestion	Observed	45	205
	Expected	58.0	192.0
	Chi-square	**2.9**	0.9
Weather condition	Observed	73	177
	Expected	58.0	192.0
	Chi-square	**3.9**	1.2
Special events	Observed	87	163
	Expected	58.0	192.0
	Chi-square	**14.5**	**4.4**

Chi-Sq = 38.793, DF = 4, P-Value = 0.000

Tables 3.4 and 3.5 clearly indicate that the drivers' response to messages displaying accident occurrence or roadwork activities or traffic congestion is less than expected by answering that they will never or rarely give "negative" response to such messages. On the other hand, the drivers' response to messages displaying special events occurrence or adverse weather information is more than expected by answering that they will never or rarely give "negative" response to such messages, and less than expected by answering that they will usually or always "positive" response to such messages. The above situation is contributing significantly to the χ^2 of the tables. It means that the drivers act seriously with messages like accident occurrence, roadwork activities, or traffic congestion more than the other types of messages.

The percentage of observed responses from Table 3.5 above and its confidence interval are summarized in Table 3.6.

Table 3.6: Drivers' response and its confidence interval.

VMS display	Negative response	Positive response
Accident occurrence	0.160 (0.115-0.205)	0.840 (0.795-0.885)
Roadwork activities	0.180 (0.132-0.228)	0.820 (0.772-0.868)
Traffic congestion	0.180 (0.132-0.228)	0.820 (0.772-0.868)
Weather condition	0.292 (0.236-0.348)	0.708 (0.652-0.764)
Special event	0.348 (0.289-0.407)	0.652 (0.593-0.711)

Table 3.6 clearly indicates that the drivers tend to act positively to all messages displayed in the VMS since there are no intersecting values in the table, even if there are some differences in the responses based on message display.

3.5.2 Effect of Drivers' Personal Characteristics

Drivers' personal characteristics were statistically analyzed with their familiarity and response to different messages displayed on VMS. It was found that some characteristics have significant relation with some of these messages, while others are not significant. Table 3.7 summarizes these relations.

Table 3.7: Relation of reason of diversion displayed in VMS with drivers' personal characteristics.

Display/character	Accident occurrence	Road work activities	Congestion occurrence	Weather information	Special events
Nationality	X	X	X	√	√
Native language	X	X	X	X	√
Age	X	√	X	X	√
Driving experience	X	X	X	√	X

(X): No significant relation
(√):There is significant relation

Table 3.7 clearly indicates that the response of drivers' to accident incidents, roadwork activities, and traffic congestion have no statistical relation with their personal characteristics, except the relation between age and messages related to roadwork activities. On the other hand, the drivers' characteristics have significant relation with messages like weather information and special events occurrence. Detailed significant results and discussion are shown in the next sections, in each category of the drivers' personal characteristics. No significant relations are shown in Appendix B.

3.5.2.1 Nationality

Tables 3.8 to 3.17 test the relation between the nationality of the drivers and their knowledge and response to VMS messages information.

Table 3.8: Relation between drivers' nationality and their opinion on the effect of VMS in reducing trip time.

Nationality / Effect		No effect	Highly effective	No opinion
Saudi	Observed	60	44	18
	Expected	57.1	51.2	13.7
	Chi-square	0.2	1.02	1.4
Arabs	Observed	44	27	6
	Expected	36	32.3	8.6
	Chi-square	1.9	0.9	0.8
Other Nationalities	Observed	13	34	4
	Expected	23.9	21.4	5.7
	Chi-square	**4.9**	**7.4**	0.5

Pearson Chi-Square = 18.982, DF = 6, P-Value = 0.004

It is noticed from the above table that the observed number of drivers from other nationalities (i.e non Saudi, non Arabs) who think VMS is highly effective is more than what is expected. This means that this group has positive attitude toward the effect of

VMS in reducing trip time, and it is expected that such drivers will respond to VMS messages suggested solutions to reduce trip time.

Table 3.9: Relation between drivers' nationality and their confidence on VMS messages.

Nationality / Usefulness		Not trust	Somewhat trust	Highly trust	No opinion
Saudi	Observed	11	62	37	12
	Expected	6.3	50.8	52.7	12.2
	Chi-square	3.4	2.5	4.7	0.003
Arabs	Observed	1	30	39	7
	Expected	**4**	32	33.3	7.7
	Chi-square	2.2	0.1	1	0.1
Other Nationalities	Observed	1	12	32	6
	Expected	**2.7**	21.2	22.0	5.1
	Chi-square	1.0	4.0	4.5	0.2

Pearson Chi-Square = 23.729, DF = 6, P-Value = 0.001

In the above table, the expected value in some cells is less than 5 (highlighted). This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative confidence", as shown in Table 3.10.

Table 3.10: Relation between drivers' nationality and their confidence on VMS messages.

Nationality / Usefulness		Negative confidence	Positive confidence	No opinion
Saudi	Observed	73	37	12
	Expected	57.1	52.7	12.2
	Chi-square	**4.4**	**4.7**	0.003
Arabs	Observed	31	39	7
	Expected	36.0	33.3	7.7
	Chi-square	0.7	1	0.1
Other Nationalities	Observed	13	32	6
	Expected	23.9	22.0	5.1
	Chi-square	**4.9**	**4.5**	0.2

Pearson Chi-Square = 20.486, DF = 4, P-Value = 0.000

It is noticed from the above table that the observed number of drivers from other nationalities (i.e non Saudi, non Arabs) who have positive confidence toward VMS information is more than what is expected. On the other hand, it is clear that Saudi drivers showed an opposite attitude regarding the trust on the information provided by VMS. This may indicate that local drivers will have negative response in the future toward VMS.

Table 3.11: Relation between drivers' nationality and their opinion about the usefulness of VMS in displaying "bad weather conditions".

Nationality / Usefulness		Not useful	Somewhat useful	Highly useful	No opinion
Saudi	Observed	3	52	60	7
	Expected	5.4	39	70.7	6.8
	Chi-square	1	4.3	1.6	0.004
Arabs	Observed	4	15	54	4
	Expected	**3.4**	24.6	44.7	**4.3**
	Chi-square	0.11	3.8	1.9	0.02
Other Nationalities	Observed	4	13	31	3
	Expected	**2.2**	16.3	29.6	**2.9**
	Chi-square	1.4	0.6	0.06	0.007

Pearson Chi-Square = 14.970, DF = 6, P-Value = 0.020

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative opinion", and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.12.

Table 3.12: Relation between drivers' nationality and their opinion about the usefulness of VMS in displaying "bad weather conditions".

Nationality / Usefulness		Negative opinion	Positive opinion
Saudi	Observed	55	60
	Expected	44.3	70.7
	Chi-square	2.6	1.6
Arabs	Observed	19	54
	Expected	28.1	44.8
	Chi-square	**3.0**	1.9
Other Nationalities	Observed	17	31
	Expected	18.5	29.5
	Chi-square	0.1	0.08

Pearson Chi-Square = 9.208, DF = 2, P-Value = 0.010

It is noticed from the above table that the observed number of Arabs drivers who think VMS is not useful in displaying weather information is less than what is expected. This may indicate that Arab drivers will have positive response in the future toward this type of VMS messages.

Table 3.13: Relation between drivers' nationality and their opinion about the usefulness of VMS in displaying "roadwork activities".

Nationality / usefulness		Not useful	Somewhat useful	Highly useful	No opinion
Saudi	Observed	4	28	83	7
	Expected	**2.9**	23.4	90.8	**4.9**
	Chi-square	0.4	0.9	0.7	0.9
Arabs	Observed	1	6	69	1
	Expected	**1.9**	14.8	57.3	**3.1**
	Chi-square	0.4	5.2	2.4	1.4
Other Nationalities	Observed	1	14	34	2
	Expected	**1.2**	9.8	37.9	**2.0**
	Chi-square	0.04	1.8	0.4	0.001

Pearson Chi-Square = 14.540, DF = 6, P-Value = 0.024

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title “Negative opinion”, and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.14.

Table 3.14: Relation between drivers’ nationality and their opinion about the usefulness of VMS in displaying “roadwork activities”.

Nationality / Usefulness		Negative opinion	Positive opinion
Saudi	Observed	32	83
	Expected	25.9	89.1
	Chi-square	1.5	0.4
Arabs	Observed	7	69
	Expected	17.1	58.9
	Chi-square	**5.9**	1.7
Other Nationalities	Observed	15	34
	Expected	11.0	37.9
	Chi-square	1.4	0.4

Pearson Chi-Square = 11.417, DF = 2, P-Value = 0.003

It is noticed from the above table that the observed number of Arabs drivers who think VMS is not useful in displaying roadwork activities is less than what is expected. Again, it is expected that drivers from Arab countries will have positive response in the future toward this type of VMS messages.

Table 3.15: Relation between drivers’ nationality and their opinion about the usefulness of VMS in displaying “alternative routes”.

Nationality / usefulness		Not useful	Somewhat useful	Highly useful	No opinion
Saudi	Observed	7	33	71	11
	Expected	**4.4**	26.4	81	10.3
	Chi-square	1.5	1.7	1.2	0.06
Arabs	Observed	2	9	65	1
	Expected	**2.8**	16.6	51.1	6.5
	Chi-square	0.2	3.5	3.7	4.6
Other Nationalities	Observed	0	12	30	9
	Expected	**1.8**	11	33.9	**4.3**
	Chi-square	1.8	0.09	0.44	5.2

Pearson Chi-Square = 24.177, DF = 6, P-Value = 0.000

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative opinion", and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.16.

Table 3.16: Relation between drivers' nationality and their opinion about the usefulness of VMS in displaying "alternative routes".

Nationality / Usefulness		Negative opinion	Positive opinion
Saudi	Observed	40	71
	Expected	30.5	80.5
	Chi-square	**2.9**	1.1
Arabs	Observed	11	65
	Expected	20.9	55.1
	Chi-square	**4.7**	1.8
Other Nationalities	Observed	12	30
	Expected	11.5	30.5
	Chi-square	0.02	0.007

Pearson Chi-Square = 10.546, DF = 2, P-Value = 0.005

It is noticed from the above table that the observed number of Arab drivers who think VMS not useful in displaying alternative routes is less than what is expected. While the observed number of Saudi drivers are more than expected. This may indicate that drivers from Arab countries will have positive response in the future toward this type of VMS messages.

Table 3.17: Relation between drivers' nationality and the difficulty to see and read portable VMS.

Nationality / difficulty		Very difficult	Somewhat difficult	Very easy	No opinion
Saudi	Observed	15	57	31	19
	Expected	14.2	53.7	33.2	21
	Chi-square	0.05	0.2	0.1	0.2
Arabs	Observed	7	41	15	14
	Expected	9	33.9	20.9	13.2
	Chi-square	0.4	1.5	1.7	0.04
Other Nationalities	Observed	7	12	22	10
	Expected	5.9	22.4	13.9	8.8
	Chi-square	0.2	**4.8**	**4.8**	0.2

Pearson Chi-Square = 14.222, DF = 6, P-Value = 0.027

It is noticed from the above table that the observed number of drivers from other nationalities (i.e non Saudi, non Arabs) who think portable VMS is difficult to read is less than what is expected. And more than expected by thinking that portable VMS is easy to see and read. This means that they gave a positive attitude more than other drivers toward the difficulty to see and read portable message signs.

For the analysis of the last part of the interviews on drivers' nationality, the expected value in some cells in the significant tables is less than 5, which is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative response". Similarly, the third and fourth columns were consolidated into one column as "Positive response". Although some tables are significant, but examining each cell, it is clear that all chi-square values are less than 2.7. Some relation became not significant due to consolidation, while others are significant as shown in Tables 3.18 and 3.19.

Table 3.18: Effect of nationality on drivers' response to weather condition information in VMS.

Nationality / Response		Negative response	Positive response
Saudi	Observed	48	74
	expected	35.6	86.4
	Chi-square	**4.3**	1.8
Arabs	Observed	15	62
	expected	22.5	54.5
	Chi-square	2.5	1
Other Nationalities	Observed	10	41
	expected	14.9	36.1
	Chi-square	1.6	0.7

Pearson Chi-Square = 11.861, DF = 2, P-Value = 0.003

The above table clearly indicates that nationalities affect the drivers' response to weather conditions messages displayed on VMS. In particular, the effect appears for Saudi drivers wherein they tend to act negatively with VMS. This is manifested by the fact that the observed number of drivers who gave 'negative response" to VMS is much higher than the expected value. The above situation is contributing significantly to the χ^2 of the table.

Table 3.19: Effect of nationality on drivers' response to special events information in VMS.

Nationality / Response		Negative response	Positive response
Saudi	Observed	48	74
	Expected	42.9	79.1
	Chi-square	0.6	0.3
Arabs	Observed	30	47
	Expected	27.1	49.9
	Chi-square	0.3	0.2
Other Nationalities	Observed	10	41
	Expected	17.9	33.1
	Chi-square	**3.5**	1.9

Pearson Chi-Square = 6.832, DF = 2, P-Value = 0.033

It is noticed from the above table that the observed number of drivers from other nationalities (i.e non Saudi, non Arabs) who gave 'negative response" to VMS is much lower than the expected value. This means that they have a positive indication toward this type of messages in VMS.

Summary

It is clear from the above analysis that nationality has no statistical significant impact on drivers' response to messages related to accident occurrence, roadwork activities, and congestion occurrence. On the other hand, nationality has statistical significant relation with the other messages (weather information and special events occurrence) where expatriate drivers showed positive attitude toward VMS compared to native local drivers. It is expected that such indications are derived from the fact that local drivers know that adverse weather and special events rarely occurred in this area.

3.5.2.2 Native Language

Tables 3.20 to 3.25 test the relation between native language of the drivers and their knowledge and response to VMS messages information.

Table 3.20: Relation between drivers' native language and their opinion on the effect of VMS in reducing trip time.

Native Language / Effect		No effect	Somewhat effective	Highly effective	No opinion
Arabic	Observed	23	80	71	24
	Expected	20.6	72.1	83.2	22.2
	Chi-square	0.3	0.8	1.8	0.15
Other Languages	Observed	3	11	34	4
	Expected	5.4	18.9	21.8	5.8
	Chi-square	1.1	**3.3**	**6.8**	0.6

Pearson Chi-Square = 14.816, DF = 3, P-Value = 0.002

It is noticed from the above table that the observed number of non Arabic speakers who think VMS not useful in reducing trip time is less than what is expected. It means that this group of drivers have positive thinking toward the VMS information and it is expected from them to highly respond to VMS.

Table 3.21: Relation between drivers' native language and their confidence on VMS messages.

Native Language / Confidence		Not trust	Somewhat trust	Highly trust	No opinion
Arabic	Observed	12	91	76	19
	Expected	10.3	82.4	85.5	19.8
	Chi-square	0.3	0.9	1.1	0.03
Other Languages	Observed	1	13	32	6
	Expected	**2.7**	21.6	22.5	5.8
	Chi-square	1.1	3.4	4	0.1

Pearson Chi-Square = 10.972, DF = 3, P-Value = 0.012

In the above table, the expected value in some cells is less than 5 (highlighted), which is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative confidence", as shown in Table 3.22.

Table 3.22: Relation between drivers' native language and their confidence on VMS messages.

Native Language / Confidence		Negative confidence	Positive confidence	No opinion
Arabic	Observed	103	76	19
	Expected	92.7	85.5	19.8
	Chi-square	1.2	1.1	0.03
Other Languages	Observed	14	32	6
	Expected	24.3	22.5	5.2
	Chi-square	**4.4**	**4.0**	0.1

Pearson Chi-Square = 10.809, DF = 2, P-Value = 0.004

It is noticed from the above table that the observed number of non Arabic speakers who have positive confidence toward VMS information is more than what is expected. Again, this means that this group of drivers have positive thinking toward the VMS information and it is expected from them to highly respond to VMS.

Table 3.23: Relation between drivers' native language and their opinion about the usefulness of VMS in displaying "alternative routes".

Native Language / Usefulness		Not useful	Somewhat useful	Highly useful	No opinion
Arabic	Observed	9	42	135	12
	Expected	7.1	42.8	131.5	16.6
	Chi-square	0.5	0.01	0.09	1.3
Other Languages	Observed	0	12	31	9
	Expected	**1.9**	11.2	34.5	**4.4**
	Chi-square	1.9	0.05	0.4	4.9

Pearson Chi-Square = 9.087, DF = 3, P-Value = 0.028

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative opinion", and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.24.

Table 3.24: Relation between drivers' native language and their opinion about the usefulness of VMS in displaying "alternative routes".

Native Language / Usefulness		Negative opinion	Positive opinion
Arabic	Observed	51	135
	Expected	51.2	134.8
	Chi-square	0.001	0.000
Other Languages	Observed	12	31
	Expected	11.8	31.2
	Chi-square	0.002	0.001

Pearson Chi-Square = 0.004, DF = 1, P-Value = 0.949

It is noticed that the above table is not significant since the p-value is more than 0.1, so there is no conclusion from this table.

Table 3.25: Relation between drivers' native language and their opinion about the difficulty to see and read portable VMS.

Native language / Difficulty		Very difficult	Somewhat difficult	Very easy	No opinion
Arabic	Observed	22	97	46	33
	Expected	23	87.1	53.9	34.1
	Chi-square	0.04	1.1	1.1	0.03
Other languages	Observed	7	13	22	10
	Expected	6	22.9	14.1	8.9
	Chi-square	0.15	**4.3**	**4.4**	0.1

Pearson Chi-Square = 11.250, DF = 3, P-Value = 0.010

It is noticed from the above table that the observed number of non Arabic speakers who think portable VMS is difficult to read is less than what is expected. This means that this group of drivers have positive thinking toward portable VMS, and it is expected from them to respond to it.

For the analysis of the last part of the interviews with drivers' native language, the expected value in some cells in the significant tables is less than 5, which is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative response". Similarly, the third and fourth columns were consolidated into one column as "Positive response". Some relation became not significant due to consolidation, while others are significant as shown in Table 3.26.

Table 3.26: Effect of native language on drivers' response to special events information in VMS.

Native language / Response		Negative	Positive
Arabic	Observed	77	121
	Expected	69.7	128.3
	Chi-square	0.8	0.4
Other languages	Observed	11	41
	Expected	18.3	33.7
	Chi-square	**2.9**	1.5

Pearson Chi-Square = 5.679, DF = 1, P-Value = 0.017

The above table indicates that native language affects the drivers' response to VMS. In particular, the effect appears for the non-Arabic where the drivers tend to act positively with VMS. This is manifested by the fact that the observed number of drivers who negatively responded to VMS is much smaller than the expected value. The above situations are contributing significantly to the χ^2 of the table.

Summary

Native language has no statistical significant impact on accident occurrence, roadwork activities, congestion occurrence, and weather information messages, while it has statistical significant relation with special events occurrence messages, where non-Arabic speakers showed positive attitude toward VMS compared to native local drivers.

3.5.2.3 Age

Tables 3.27 to 3.32 test the relation between the age of the drivers and their knowledge and response to VMS messages information.

Table 3.27: Relation between drivers' age and their familiarity with VMS.

Age (years) / Familiarity		Never heard	Never experienced	Occasionally experienced	Very familiar
Less than 20	Observed	6	12	14	12
	Expected	6.3	9.2	18.3	10.2
	Chi-square	0.02	0.9	1.0	0.3
20-30	Observed	19	24	69	30
	Expected	20.4	29.5	59.1	32.9
	Chi-square	0.1	1	1.7	0.3
30-40	Observed	11	10	12	9
	Expected	6.1	8.7	17.5	9.7
	Chi-square	4	0.2	1.7	0.05
More than 40	Observed	0	6	9	7
	Expected	**3.2**	**4.6**	9.2	5.1
	Chi-square	3.2	0.44	0.002	0.7

Pearson Chi-Square = 15.629, DF = 9, P-Value = 0.075

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the last two rows of age intervals were consolidated into one row under the category "More than 30", as shown in Table 3.28.

Table 3.28: Relation between drivers' age and their familiarity with VMS.

Age (years) / Familiarity		Never heard	Never experienced	Occasionally experienced	Very familiar
Less than 20	Observed	6	12	14	12
	Expected	6.3	9.2	18.3	10.2
	Chi-square	0.02	0.9	1.0	0.3
20-30	Observed	19	24	69	30
	Expected	20.4	29.5	59.1	32.9
	Chi-square	0.1	1.0	1.7	0.3
More than 30	Observed	11	16	21	16
	Expected	9.2	13.3	26.6	14.9
	Chi-square	0.3	0.5	1.2	0.09

Pearson Chi-Square = 7.468, DF = 6, P-Value = 0.280

It is noticed that the above table is not significant since the p-value is more than 0.1, so there is no conclusion from this table.

Table 3.29: Relation between drivers' age and their opinion about the effect of VMS in reducing trip time.

Age (years) / Effect		No effect	Somewhat effective	Highly effective	No opinion
Less than 20	Observed	6	23	8	7
	Expected	**4.6**	16	18.5	**4.9**
	Chi-square	0.4	3.1	5.9	0.9
20-30	Observed	12	46	68	16
	Expected	14.8	51.7	59.6	15.9
	Chi-square	0.52	0.6	1.2	0.0006
30-40	Observed	5	14	18	5
	Expected	**4.4**	15.3	17.6	**4.7**
	Chi-square	0.1	0.1	0.007	0.02
More than 40	Observed	3	8	11	0
	Expected	**2.3**	8	9.2	**2.5**
	Chi-square	0.2	0.0	0.3	2.5

Pearson Chi-Square = 15.867, DF = 9, P-Value = 0.070

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative effect", and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.30.

Table 3.30: Relation between drivers' age and their opinion about the effect of VMS in reducing trip time.

Age (years) / Effect		Negative effect	Positive effect
Less than 20	Observed	29	8
	Expected	19.5	17.5
	Chi-square	**4.6**	**5.2**
20-30	Observed	58	68
	Expected	66.4	59.6
	Chi-square	1.0	1.2
30-40	Observed	19	18
	Expected	19.5	17.5
	Chi-square	0.01	0.01
More than 40	Observed	11	11
	Expected	11.6	10.4
	Chi-square	0.03	0.03

Pearson Chi-Square = 12.126, DF = 3, P-Value = 0.007

It is noticed from the above table that the observed number of young drivers (less than 20 years old) who think VMS not useful in reducing trip time is more than what is expected. This means that young drivers (less than 20 years) may be less confident with VMS, and it is expected that they have negative response to VMS messages.

Table 3.31: Relation between drivers' age and their opinion about the effect of VMS in reducing drivers stresses.

Age (years) / Effect		No effect	Somewhat effective	Highly effective	No opinion
Less than 20	Observed	6	18	19	1
	Expected	**2.8**	19.7	17.8	**3.7**
	Chi-square	3.6	0.15	0.08	2
20-30	Observed	9	63	52	18
	Expected	9	63.6	57.4	11.9
	Chi-square	0.0	0.006	0.5	3.1
30-40	Observed	1	23	16	2
	Expected	**2.7**	18.8	17	**3.5**
	Chi-square	1.1	0.9	0.05	0.66
More than 40	Observed	0	8	14	0
	Expected	**1.4**	9.9	8.9	**1.8**
	Chi-square	1.4	0.35	2.9	1.8

Pearson Chi-Square = 18.653, DF = 9, P-Value = 0.028

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative effect", and the fourth column (No opinion) was considered as missing answers, as shown in Table 3.32.

Table 3.32: Relation between drivers' age and their opinion about the effect of VMS in reducing drivers stresses.

Age (years) / Effect		Negative effect	Positive effect
Less than 20	Observed	24	19
	Expected	24.0	19.0
	Chi-square	0.0	0.0
20-30	Observed	72	52
	Expected	69.3	54.7
	Chi-square	0.1	0.1
30-40	Observed	24	16
	Expected	22.4	17.6
	Chi-square	0.1	0.2
More than 40	Observed	8	14
	Expected	12.3	9.7
	Chi-square	1.5	1.9

Pearson Chi-Square = 3.915, DF = 3, P-Value = 0.271

It is noticed that the above table is not significant since the p-value is more than 0.1, and even if the last two rows of age intervals are consolidated into one row, the situation is still not significant with p-value of 0.705, so there is no conclusion from this table.

For the analysis of the last part of the interviews with drivers' age, the expected value in some cells in the significant tables is less than 5, which is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative response". Similarly, the third and fourth columns were consolidated into one column as "Positive response". Some relation became not significant due to consolidation, while others are significant as shown in Tables 3.33, 3.34 and 3.35.

Table 3.33: Effect of age on drivers' response to any instantaneous traffic information provided in VMS.

Age (years) / Response		Negative	Positive
Less than 20	Observed	15	29
	Expected	9.9	34.1
	Chi-square	**2.7**	0.8
20-30	Observed	25	117
	Expected	31.8	110.2
	Chi-square	1.5	0.4
More than 30	Observed	16	48
	Expected	14.4	49.7
	Chi-square	0.2	0.05

Pearson Chi-Square = 5.586, DF = 2, P-Value = 0.061

The above table indicates that age affects the drivers' response to VMS. In particular, the effect appears for the drivers less than 20 years old where they tend to act negatively with VMS. This is manifested by the fact that the observed number of drivers who gave "Negative response" to VMS is much larger than the expected value. The above situation is contributing significantly to the χ^2 of the table.

Table 3.34: Effect of age on drivers' response to roadwork information in VMS.

Age (years) / Response		Negative	Positive
Less than 20	Observed	15	29
	Expected	8.1	35.9
	Chi-square	**5.9**	1.3
20-30	Observed	21	121
	Expected	26.1	115.9
	Chi-square	1	0.2
More than 30	Observed	10	54
	Expected	11.7	52.2
	Chi-square	0.3	0.06

Pearson Chi-Square = 8.777, DF = 2, P-Value = 0.012

The above table indicates that age affects the drivers' response to VMS. In particular, the effect appears for the drivers less than 20 years old where they tend to act negatively with VMS. This is manifested by the fact that observed number of drivers who gave "Negative response" to VMS is much larger than the expected value. The above situation is contributing significantly to the χ^2 of the table. This situation indicates that young drivers are not expected to respond to VMS.

Table 3.35: Effect of age on drivers' response to special events information in VMS.

Age (years) / Response		Negative	Positive
Less than 20	Observed	22	22
	Expected	15.5	28.5
	Chi-square	**2.7**	1.5
20-30	Observed	51	91
	Expected	50	92
	Chi-square	0.02	0.01
More than 30	Observed	15	49
	Expected	22.5	41.5
	Chi-square	2.5	1.4

Pearson Chi-Square = 8.139, DF = 2, P-Value = 0.017

It is noticed from the above table that young drivers (less than 20 years) are more than expected by answering that they will not adjust their route due to accident information provided by VMS.

Summary

Age has no statistical significant impact on accident occurrence, congestion occurrence, and weather information messages, while it has statistical significant relation with roadwork and special events occurrence messages, where young drivers (below 20 years old) declared little enthusiasm to respond positively to such traffic related VMS. This may be related to the fact that young drivers are more prone to violate traffic regulations in general.

3.5.2.4 Driving Experience

Tables 3.36 to 3.39 test the relation between driving experience of the drivers and their knowledge and response to VMS messages information.

Table 3.36: Relation between drivers driving experience and their opinion about the effect of VMS in reducing trip time.

Experience (years) / Effect		No effect	Somewhat effective	Highly effective	No opinion
Less than 3	Observed	11	31	25	9
	Expected	7.9	27.7	31.9	8.5
	Chi-square	1.2	0.4	1.5	0.03
3-6	Observed	7	26	51	13
	Expected	10.1	35.3	40.7	10.9
	Chi-square	0.9	2.5	2.6	0.4
6-9	Observed	2	14	15	5
	Expected	**3.7**	13.1	15	**4**
	Chi-square	0.8	0.06	0.0	0.2
More than 9	Observed	6	20	14	1
	Expected	**4.2**	14.9	17.2	**4.6**
	Chi-square	0.7	1.7	0.6	**2.8**

Pearson Chi-Square = 16.498, DF = 9, P-Value = 0.057

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the last two rows of driving experience intervals were consolidated into one row under the category "More than 6", as shown in Table 3.37.

Table 3.37: Relation between drivers driving experience and their opinion about the effect of VMS in reducing trip time.

Experience (years) / Effect		No effect	Somewhat effective	Highly effective	No opinion
Less than 3	Observed	11	31	25	9
	Expected	7.9	27.7	32.0	8.2
	Chi-square	1.2	0.4	1.5	0.07
3-6	Observed	7	26	51	13
	Expected	10.1	35.5	40.9	10.5
	Chi-square	0.9	**<u>2.5</u>**	**<u>2.5</u>**	0.6
More than 6	Observed	8	34	29	5
	Expected	7.9	27.8	32.0	8.2
	Chi-square	0.001	1.4	0.3	1.3

Pearson Chi-Square = 12.701, DF = 6, P-Value = 0.048

It is noticed from the above table that the observed number of drivers with 3-6 years of driving experience who think VMS not useful in reducing trip time is less than what is expected. The above situation is contributing significantly to the χ^2 of the table. This may indicate that this group will respond positively to such VMS messages.

Table 3.38: Relation between drivers driving experience and their opinion about the usefulness of VMS in displaying “weather condition”.

Experience (years) / Usefulness		Not useful	Somewhat useful	Highly useful	No opinion
Less than 3	Observed	5	16	54	1
	Expected	**3.3**	24.3	44.1	**4.3**
	Chi-square	0.8	2.8	2.2	2.5
3-6	Observed	3	38	47	9
	Expected	**4.3**	31.0	56.3	5.4
	Chi-square	0.4	1.5	1.5	2.3
6-9	Observed	2	12	19	3
	Expected	**1.6**	11.5	20.9	**2**
	Chi-square	0.1	0.02	0.2	0.5
More than 9	Observed	1	14	25	1
	Expected	**1.8**	13.1	23.8	**2.3**
	Chi-square	0.4	0.06	0.06	0.7

Pearson Chi-Square = 16.185, DF = 9, P-Value = 0.063

In the above table, the expected value in some cells is less than 5. This is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title “Negative opinion”, and the fourth column (No opinion) was considered as missing answers. The last two rows of driving experience intervals were consolidated into one row under the category “More than 6”, as shown in Table 3.39.

Table 3.39: Relation between drivers driving experience and their opinion about the usefulness of VMS in displaying “weather condition”.

Experience (years) / Usefulness		Negative opinion	Positive opinion
Less than 3	Observed	21	54
	Expected	28.9	46.1
	Chi-square	**2.2**	1.4
3-6	Observed	41	47
	Expected	33.9	54.1
	Chi-square	1.5	0.9
More than 6	Observed	29	44
	Expected	28.2	44.9
	Chi-square	0.03	0.02

Pearson Chi-Square = 5.968, DF = 2, P-Value = 0.051

It is noticed from the above table that the observed number of drivers with less than 3 years of driving experience who think VMS not useful in displaying weather information is less than what is expected. This may indicate that less experienced drivers tend to act positively with VMS.

For the analysis of the last part of the interviews with drivers driving experience, the expected value in some cells in the significant tables is less than 5, which is statistically not acceptable. Therefore, the first two columns were consolidated into one column under the title "Negative response". Similarly, the third and fourth columns were consolidated into one column as "Positive response". Some relation became not significant due to consolidation, while others are significant as shown in Tables 3.40 and 3.41.

Table 3.40: Effect of driving experience on drivers' response to weather condition information in VMS.

Experience (years) / Response		Never	Rarely	Usually	Always
Less than 3	Observed	5	9	33	29
	Expected	**3.95**	18.3	31.0	22.8
	Chi-square	0.3	4.7	0.1	1.7
3-6	Observed	3	31	36	27
	Expected	5.0	23.3	39.6	29.1
	Chi-square	0.8	2.5	0.3	0.2
6-9	Observed	4	11	11	10
	Expected	**1.9**	8.6	14.7	10.8
	Chi-square	2.5	0.6	0.9	0.06
More than 9	Observed	1	9	22	9
	Expected	**2.1**	9.8	16.7	12.3
	Chi-square	0.6	0.07	1.6	0.9

Pearson Chi-Square = 17.904, DF = 9, P-Value = 0.036

Table 3.41: Effect of driving experience on drivers' response to weather condition information in VMS.

Experience (years) / Response		Negative	Positive
Less than 3	Observed	14	62
	Expected	22.2	53.8
	Chi-square	**3.0**	1.2
3-6	Observed	34	63
	Expected	28.3	68.7
	Chi-square	1.1	0.5
More than 6	Observed	25	52
	Expected	22.5	54.5
	Chi-square	0.3	0.1

Pearson Chi-Square = 6.275, DF = 2, P-Value = 0.043

The above two tables clearly indicate that driving experience affects the drivers' response to VMS. In particular, the effect appears for the drivers with less than 3 years driving experience where they tend to act positively with VMS. This is manifested by the fact that observed number of drivers who gave negative response to VMS is much less than the expected value. The above situation is contributing significantly to the χ^2 of the table.

Summary

Driving experience has no statistical significant impact on messages for accident occurrence, roadwork activities, congestion occurrence, and special events occurrence, while it has statistical significant relation with weather information messages, where drivers with less than 3 years driving experience showed positive attitude toward VMS compared to highly experienced drivers.

3.6 The Binary Logistic Regression Model

It was clearly appeared from the previous sections that drivers personal characteristics have statistical relations with the VMS content messages. And to know the effect of each character in diversion percentage, the following model was built. The term logit was first used by Berkson in 1944. In the binary regression model, the predicted values for the dependent (response) variable will never be less than (or equal to) 0, or greater than (or equal to) 1, regardless of the values of the independent variables. It is therefore commonly used to analyze binary dependent variable. The simplicity of binary choice situations makes it possible to develop a range of practical models, which is more than feasible in more complicated choice situations. The binary logit model is accomplished by applying the following regression equations:

$$Y = \exp(bo+b1*X1+\ldots..+bn*Xn)/\{1+\exp(bo+b1*X1+\ldots..+bn*Xn)\}$$

Developing such model aims to evaluate the variables influencing driver selection of route collectively due to VMS messages, with relative coefficient of each variable. It can easily recognize that, regardless of the regression coefficients or the magnitude of the X values, this model will always produce predicted values of Y in the range of 0 to 1 (Cramer, 2001).

The analysis was conducted using Minitab software. Based on the above concept, the probability of a driver to divert to alternative route based on any VMS message information depends on the drivers personal characteristics that statistically affect the driver decision to divert (nationality, age, and driving experience) as shown in Table 3.42.

Table 3.42: Logistic regression table.

Predictor	Coef	Error	t-statistics
Constant	0.442	0.343	1.29
Nationality	0.571	0.316	1.83
Age	0.932	0.395	2.36
Driving experience	-0.649	0.354	-1.83

Two categories were established for each personal character of the drivers. For nationality: (0) for local drivers and (1) for expatriate drivers. For native language: (0) for Arabic speakers and (1) for non-Arabic speakers. For age: (0) for young drivers (less than 20 years old) and (1) for old drivers. For driving experience: (0) for low driving experience (less than 6 years), and (1) for high driving experience.

It appears clearly from the above table that age is the most effective in diversion probability, then nationality and driving experience. All the factors behave as expected from the previous analysis where non Saudi drivers have higher probability of diversion, the older the driver the more diversion probability, less driving experience represent more diversion probability also. It seems that more experience drivers are irresponsive to VMS messages, it might be that these drivers older in age with less familiarity and trust with new technology.

It is important to know that the model was calibrated on 2/3 the sample size (160 drivers) and tested on the remaining sample (90 drivers). The goodness of fit measures for this model are based on the following (Ben-Akiva and Lerman, 1985):

L(0) = -75.257 (value of the log likelihood function when all parameters are zero) (choice 0.5 for each alternative).

L(B) = -15.12 (value of the log likelihood function at its maximum) (constant and nationality and age take 1, driving experience take 0).

L(C) = -53.87 (value of the log likelihood function when only constant is included).

p2 (informal goodness of fit index, analogous to R2 used in regression) can be calculated in two equations:

$p2 = 1 - (L(B) / L(0)) = 0.79$ or $p2 = 1 - (L(B) / L(C)) = 0.72$

Both values lie between 0 and 1, indicating a good predicting power.

The results of the first approach (interviews) were used to establish a binary logistic model relating the probability of diversion to certain drivers' personal characteristics. The resultant model indicated that nationality, age, and driving experience have significant effect on diversion rate.

Summary

It was noticed from the previous analysis that about 36% of the drivers in the sample stated that they never heard about VMS or experienced it. More than 80% of the drivers indicated that VMS is useful in improving traffic conditions, and the same percentage indicated that they trust the information provided in VMS.

On average, about 77% of the interviewed drivers indicated that they will react positively to VMS if used in the field to relay messages related to the instantaneous traffic conditions. It appears that most of the drivers act positively with messages like accident occurrence, roadwork activities, or traffic congestion more than the other types of messages with no significant relation with their personal characteristics except for those young drivers who were found to be affected by messages related to roadwork activities.

On the other hand, drivers' characteristics have significant relation with messages like weather condition and special events occurrence. It seems that such messages are not familiar to the drivers and they have different response rates to it.

CHAPTER 4

VMS EVALUATION THROUGH FIELD EXPERIMENT

4.1 Introduction

This part of the experimental work in this study focused on the response of the drivers to VMS usage by describing the relationship between the existence of VMS messages and driver route diversion rates. If different diversion rates appear with the message shown on the road rather than without it, then the message usage can be considered as a useful traffic control device that enhances traffic efficiency and reduces congestion.

4.2 Field Measurement

Effects of route altering based on VMS message were investigated in a field study on Prince Turkey Street in Al-Khobar Cornish at a normal traffic period (October, 2012). Large queues of traffic occurred during congested peak periods and blocked the right turn lane. The message advised the drivers to use the service road if they intend to turn right instead of continuing and making a right turn from the traffic light in the peak period. During the off-peak periods, the VMS displayed a general safety message, as shown in Figure 4.1.

Figure 4.1: General safety message during off-peak periods.

Generally, drivers welcome information about incidents or congestions and suggestions for alternative routes. The expectations of the drivers and the reliability of the information are two important factors to consider when showing a VMS. Since the drivers expect to get updated information, the information has to be reliable to be obeyed.

A detailed traffic count was conducted along the studied arterial for three days 24 hours daily. These days include the last two weekdays of the week and the following first day of the weekend (weekend days in Saudi Arabia are Thursday and Friday). The traffic which diverted from the arterial to the right using the slip exit ramp was monitored during congested periods for several days. Following that, the VMS was activated for several days to advise drivers who want to make a right turn at the signalized intersection to use the exit slip ramp when the intersection is very busy and the right turning lane is blocked with very long queues. The diverted traffic to the service road at the same slip exit ramp during the same congested periods was monitored for several days. Figures 4.2 to 4.5 and Tables 4.1 and 4.2 summarize the counts on the studied street in the peak four hours period.

It was found that the peak four hours period were from 8 PM to midnight on these three days. It was also found that the big difference in turning volume and percentage between the time the VMS was left blank and the time it displayed the message was during this peak period. This period is the main shopping period of the day, and it is also considered as the dinner time in the weekend when all restaurants along the road are at peak utilization.

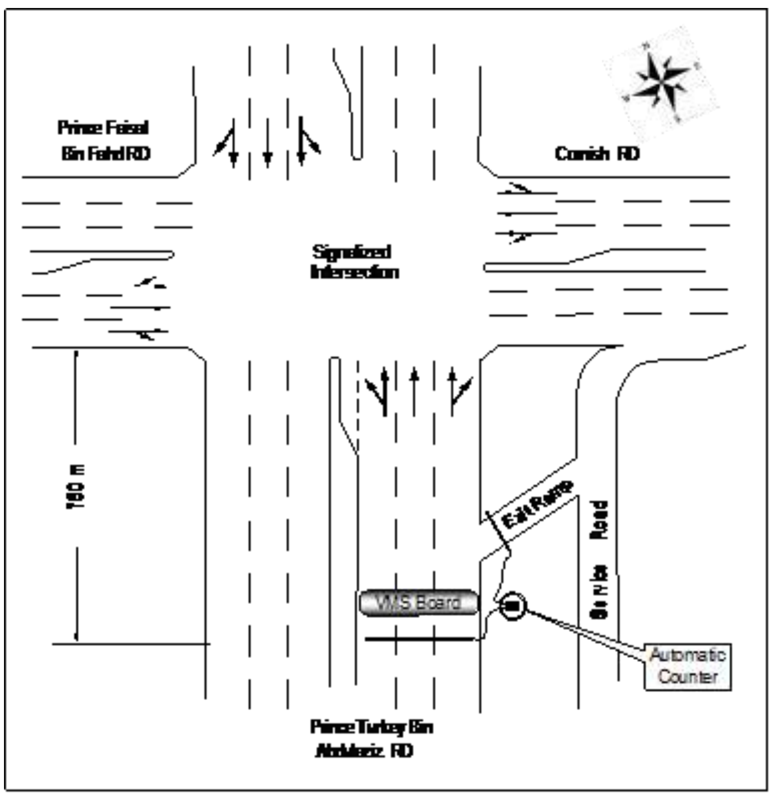

Figure 4.2: VMS location.

Table 4.1: Hourly traffic count while VMS is off.

Time	Tuesday			Wednesday			Thursday		
	Turn count	Total traffic	% Turn	Turn count	Total traffic	% Turn	Turn count	Total traffic	% Turn
8–9 PM	190	3355	5.7	326	3245	10.0	427	3532	12.1
9–10 PM	193	3599	5.4	347	3804	9.1	642	3478	18.5
10–11 PM	160	3521	4.5	389	3847	10.1	616	3158	19.5
11 PM–midnight	140	3088	4.5	343	3420	10.0	505	3284	15.4
Total	683	13563	5.0	1405	14316	9.8	2190	13452	16.3

Table 4.2: Hourly traffic count while VMS is on.

Time	Tuesday			Wednesday			Thursday		
	Turn count	Tot. count	% Turn	Turn count	Tot. traffic	% Turn	Turn count	Tot. traffic	% Turn
8–9 PM	156	3267	4.8	436	3358	13.0	724	3669	19.7
9–10 PM	200	3375	5.9	539	3819	14.1	923	3668	25.2
10–11 PM	211	3313	6.4	583	3897	15.0	897	3417	26.2
11 PM–midnight	110	2878	3.8	489	3251	15.0	779	3299	23.6
Total	677	12833	5.3	2047	14325	14.3	3323	14053	23.6

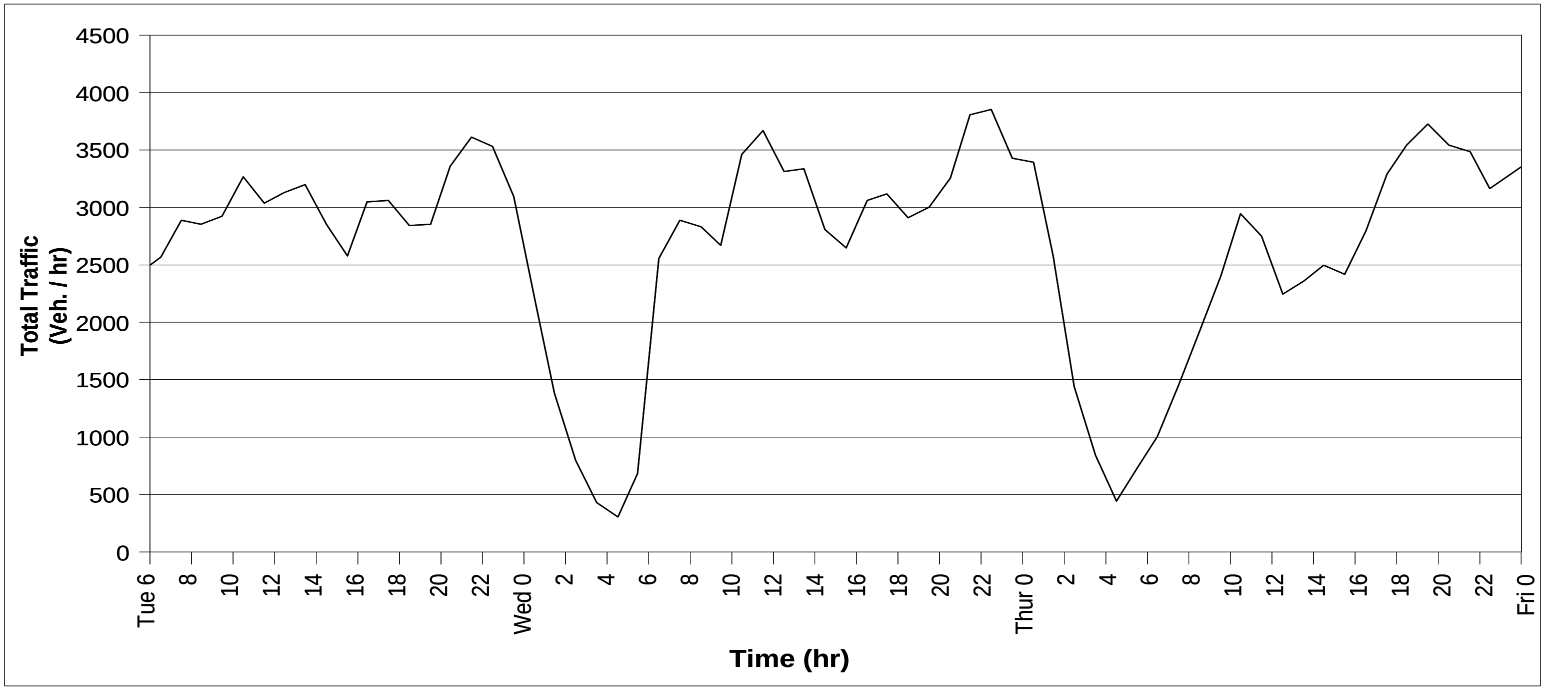

Figure 4.3: Total traffic count before the slip ramp.

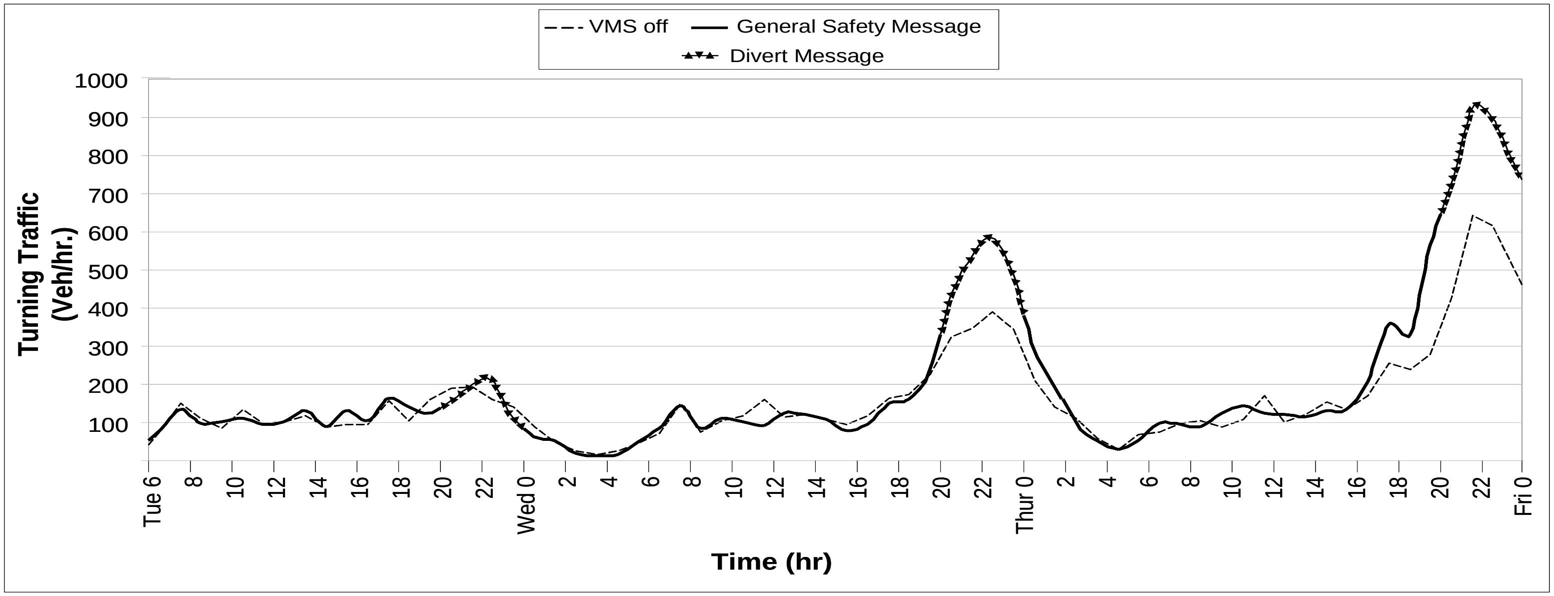

Figure 4.4: Turning traffic count at the slip ramp.

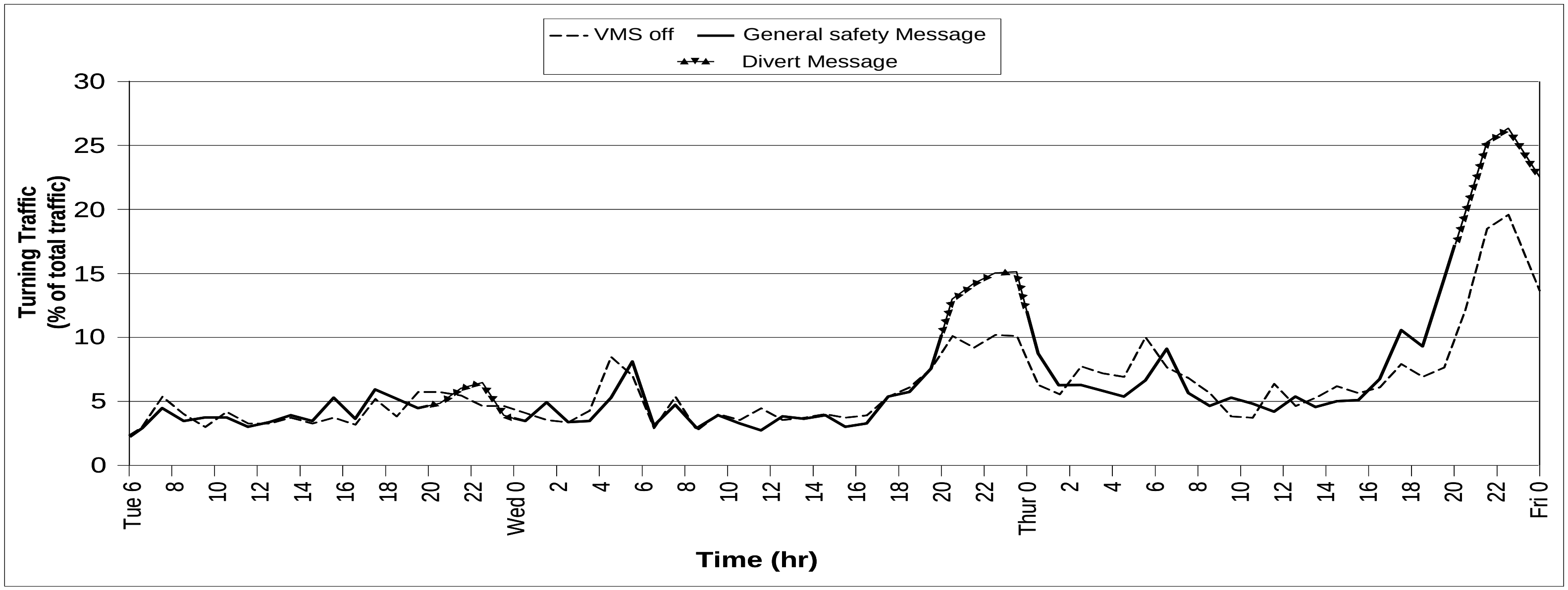

Figure 4.5: Percentage of turning traffic at the slip ramp.

4.3 Field Experiment Statistical Analysis

The statistical difference between the number of drivers who diverted while VMS displayed the message and while it was left blank without message during the peak four hours was tested using binomial probability distribution at 90% confidence level. Binomial is used if the results of each trial is either success or failure. Drivers' response to VMS can be modeled using binomial probability distribution. This test is sometimes preferred because it is simple to perform, simple to explain, and powerful enough to reject the null hypothesis when it should be rejected.

Since there was concern on the effect of the VMS, the number of drivers who diverted is considered as the success (Y), and sample size (n) is the total traffic before the slip ramp.

p^* : portion of the drivers who diverted when VMS was off.

p : portion of the drivers who diverted when VMS was on.

The test was applied on the three studied days in the peak four hours period at $\alpha = 0.1$, as shown in Tables 4.3, 4.4 and 4.5.

For example, on Thursday from 8 to 9 PM, the number of turning vehicles when VMS was off was 427 vehicles ($n = 3532$), while it was 724 vehicles when VMS was on ($n = 3669$). Applying the above concept:

$$p^* = 427/3532 = 0.121$$

$$p = 724/3669 = 0.197$$

The confidence interval at 90% confidence level was computed, where $Z_{\alpha/2} = 1.645$.

For (p*) : $0.121 \pm 1.645\sqrt{0.121 * 0.879/3532}$

$0.121 \pm 0.009 = (0.112–0.130)$

For (p) : $0.197 \pm 1.645\sqrt{0.197 * 0.803/3669}$

$0.197 \pm 0.011 = (0.186–0.208)$

Table 4.3: Portion of drivers turning and its confidence interval on **Tuesday**.

Time	VMS off	VMS on	Difference (column 3-column 2)
8–9 PM	0.057 (0.050-0.064)*	0.048 (0.042-0.054)	-0.009±0.011
9–10 PM	0.054 (0.048-0.060)	0.059 (0.052-0.066)	0.005±0.011
10–11 PM	0.045 (0.039-0.051)	0.064 (0.057-0.071)	0.019±0.011
11 PM–midnight	0.045 (0.039-0.051)	0.038 (0.032-0.044)	-0.007±0.010
Average	0.050 (0.047-0.053)	0.053 (0.050-0.056)	0.003±0.005

* 90% confidence interval

Table 4.4: Portion of drivers turning and its confidence interval on **Wednesday**.

Time	VMS off	VMS on	Difference (column 3-column 2)
8–9 PM	0.100 (0.091-0.109)*	0.130 (0.120-0.140)	0.030±0.015
9–10 PM	0.091 (0.083-0.099)	0.141 (0.132-0.150)	0.050±0.014
10–11 PM	0.101 (0.093-0.109)	0.150 (0.141-0.159)	0.049±0.015
11 PM–Midnight	0.100 (0.092-0.108)	0.150 (0.140-0.160)	0.050±0.016
Average	0.098 (0.094-0.102)	0.143 (0.138-0.148)	0.045±0.008

* 90% confidence interval

Table 4.5: Portion of drivers turning and its confidence interval on **Thursday**.

Time	VMS off	VMS on	Difference (column 3-column 2)
8–9 PM	0.121 (0.112-0.130)*	0.197 (0.186-0.208)	0.076±0.017
9–10 PM	0.185 (0.174-0.196)	0.252 (0.240-0.264)	0.067±0.019
10–11 PM	0.195 (0.183-0.207)	0.262 (0.251-0.275)	0.067±0.020
11 PM–midnight	0.154 (0.144-0.164)	0.236 (0.224-0.248)	0.082±0.019
Average	0.163 (0.158-0.168)	0.236 (0.230-0.242)	0.073±0.009

* 90% confidence interval

From Tables 4.3, 4.4, and 4.5, it can be concluded that there is no significant difference between the number of drivers who diverted when VMS was on or off during the peak four hours period on Tuesday since the intervals intersect unlike from 10-11 PM where the difference did not exceed 2%. On the other hand, the difference is significant between the number of drivers who diverted when VMS was on or off every hour of the peak four hours period on Wednesday and Thursday. This difference reached 5% on Wednesday and 8% on Thursday.

4.4 Evaluation of VMS Impact

The studied highway was simulated and analyzed using calibrated TRANSYT-7F software for Saudi Arabian streets. Since the turning difference was statistical significantly between the times the VMS was on and when it was off, the analysis was conducted to find the main improvements in MOEs between the two cases. A suitable measure of effectiveness was used to evaluate the impact of VMS by comparing the change of such MOEs on the studied highway before and after the VMS message activation. These measures could be operational like volume to capacity ratio, speed, LOS, travel time, delay, length and duration of queues, and number of stops. Other measures could be economical or environmental like vehicles emissions, fuel consumption, and accident cost.

TRANSYT-7F is an off-line macroscopic deterministic simulation and optimization model that simulates traffic as cycle flow profiles, traces the flow of cycle flow profiles from link to link throughout the network, and makes systematic changes to the offset, phase split, and cycle length of the traffic signals. It also simulates the associated traffic conditions to estimate a corresponding performance index. This index is composed of vehicle delay and number of vehicle stops.

The simulation module within the TRANSYT model evaluates the objective function that is to be minimized. The output from this software include delay, number of stops, fuel consumption, and the performance index (indicating the linear combination of the stoppages and delays within the network).

To evaluate the effect of VMS accurately along the studied road, it was decided to include the two signalized intersections around the VMS board, the downstream signalized intersection (Prince Turkey Bin Abdulaziz Street with Prince Faisal Road Intersection), and the upstream signalized intersection (Prince Turkey Bin Abdulaziz Street with King Abdullah Road intersection), as shown in Figure 4.6. This will insure that the model in Transit-7F will accurately simulate the dispersion of the traffic from the upstream intersection while moving downstream to the exit ramp or continuing to the next signalized intersection.

In the first run, the simulation was conducted with the data during the time the VMS was left blank in the peak hour in each day of the three studied days. Then the same simulation was repeated with the data during the time the VMS displayed the message in the peak hour for the same three days. The main results are summarized in Tables 4.6, 4.7 and 4.8. Appendix C contains the detailed outputs.

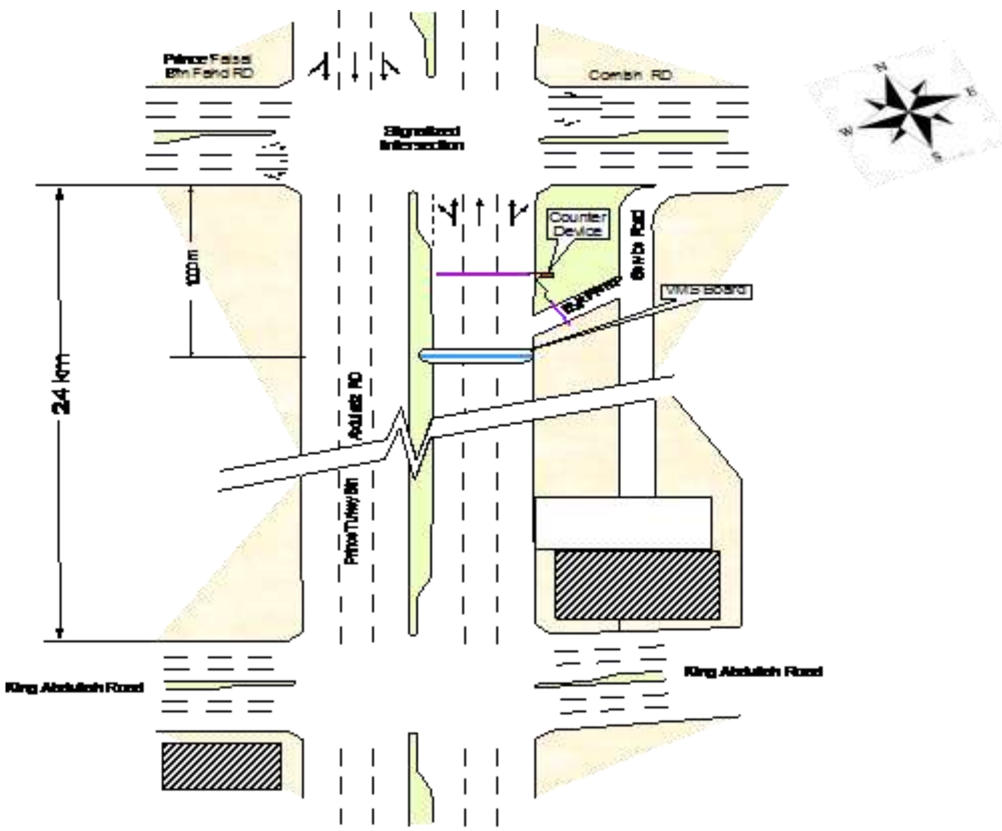

Figure 4.6: Prince Turkey Bin Abdulaziz Road.

Table 4.6: MOEs comparison between the times the VMS was on and off in the peak hour on Tuesday.

Measures	Exit Slip Ramp			Downstream Signalized Intersection		
	VMS off	VMS on	Difference Percentage*	VMS off	VMS on	Difference Percentage*
Total delay (s/veh)	0.52	0.49	0.06	1067.6	1046.7	0.02
Total stops	28.2	24.0	0.15	9809.4	9483.1	0.03
Fuel consumption (lit)	115.7	108.7	0.06	3782.6	3423.8	0.09
PI	0.7	0.6	0.14	975.5	883.2	0.09

*(VMS off-VMS on)/VMS off

Table 4.6 indicates that enhancement (reduction) in delay, stops, fuel consumption, and PI appeared after the VMS was on, in both the signalized intersection and the exit ramp.

Table 4.7: MOEs comparison between the times the VMS was on and off in the peak hour on Wednesday.

Measures	Exit Slip Ramp			Downstream Signalized Intersection		
	VMS off	VMS on	Difference Percentage*	VMS off	VMS on	Difference Percentage*
Total delay (s/veh)	0.6	0.56	0.07	1216.7	1144.8	0.06
Total stops	33.2	33.4	-0.01	9906.4	9762.4	0.01
Fuel consumption (lit)	126.6	128.1	-0.01	3924.8	3715.7	0.05
PI	0.8	0.8	0	1012.5	958.5	0.05

*(VMS off-VMS on)/VMS off

Table 4.7 indicates also that enhancement (reduction) in delay, stops, fuel consumption, and PI appeared after the VMS was on at the signalized intersection. In the exit ramp, the delay was reduced when VMS was on, while the stops and fuel consumption increased since the turning volume increased.

Table 4.8: MOEs comparison between the times the VMS was on and off in the peak hour on Thursday.

Measures	Exit Slip Ramp			Downstream Signalized Intersection		
	VMS off	VMS on	Difference Percentage*	VMS off	VMS on	Difference Percentage*
Total delay (s/veh)	0.39	0.53	-0.36	933.5	897.1	0.04
Total stops	26.9	33.7	-0.25	8999.0	8907.8	0.01
Fuel consumption (lit)	114.0	120.6	-0.06	3078.8	2970.8	0.04
PI	0.6	0.8	-0.33	794.3	766.6	0.03

*(VMS off-VMS on)/VMS off

Table 4.8 indicates also that enhancement (reduction) in delay, stops, fuel consumption, and PI appeared after the VMS was on at the signalized intersection, while in the exit ramp, delay, stops, fuel consumption, and PI increased since the turning volume increased.

From the above three tables, it appears that an average of 200 liters of fuel was saved by using the VMS during the peak hour only. Based on this fact and from economical point of view, the quantity of fuel saved in one year will reach up to 30,000 liters due to the use of VMS at this location. Considering the price of one liter of fuel in Saudi Arabia which is 0.5 Riyal, a total of 15,000 Saudi Riyals will be saved each year. The initial price of such VMS board around the world without installation and maintenance is around 100,000 Riyals. This means that within 5 years, the benefits from such technique will exceed the cost of the VMS system. This is very conservative, knowing that the peak period consist of four hours with high turning volume (not as high as peak hour). So, the saving is much more than 15,000 Riyals. This cost analysis was conducted on one item only, which is fuel saving. VMS has an effect also in enhancing safety, reducing driving stresses, delay time, and air pollution. All this is important in establishing the optimum deployment of a VMS system.

4.5 Summary

It was found that the big difference in turning volume and percentage between the time VMS was left blank and the time it displayed the message was during the peak four hours period. It was also found that there is no significant difference between the number of drivers who diverted when VMS was on or off during the peak four hours period on

Tuesday, while the difference is significant between the number of drivers who diverted when VMS was on or off every hour of the peak four hours period on Wednesday and Thursday.

In general, based on the results from the field experiment, it was found that the percentage of diverted traffic during the time the VMS displayed the message is 8% larger than the percentage of diverted traffic without activating the VMS. This percentage has an effect in reducing congestion and enhancing traffic efficiency.

CHAPTER 5

POSSIBLE APPLICATION OF VMS (DYNAMIC LANE ASSIGNMEMT)

5.1 Introduction

The reasonably good expected effect of VMS in the study area excited the researcher to use VMS technology in solving one of the bad practices in the area. The existing fixed pavement marking at intersections is expected to be less efficient in the major change of demand. At one time (for example morning time) drivers will use left and straight lanes to turn left at high left demand. While at another time (for example: afternoon time) the majority of the traffic is straight, so drivers will use only the left lane to turn left. This new possible application of VMS was studied and modeled related to dynamic lane usage concept using ARENA simulation software. This dynamic changing in lane usage in the different peak periods is expected to have significant effect in enhancing the movement of vehicles.

5.2 Dynamic Lane Assignment

Arena is an easy-to-use, powerful tool that allows the user to create and run experiments on models of any systems. Arena software provides the maximum flexibility and breadth of application coverage to model any desired level of detail and complexity. It provides an intuitive, flowchart-style environment for building an “as is” model of the process by adding real-world data. Changes can be made to the model to capture the possible scenarios to be investigated, and compare the results to find the best “to be” solution.

Changing lane usage concept was tested in one direction at a signalized intersection having two lanes. The current situation (pavement marking) at such approach is that the right lane is assigned only for drivers who intend to move through, and the left lane is shared between through and left movements at either AM or PM peak periods, as shown in Figure 5.1.

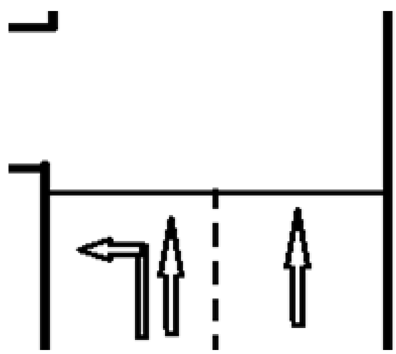

Figure 5.1: Current fixed pavement marking at AM and PM periods.

From the field observation, it was noticed that drivers usually position their vehicles in the shorter queue lane even if it is designed for the other movement. This situation is clearly noticed in the Kingdom’s intersections. Such behavior is expected to cause more delay, confusion, and accidents. It was noticed that during peak periods, the proportion of traffic on each lane is approximately what Figure 5.2 indicates.

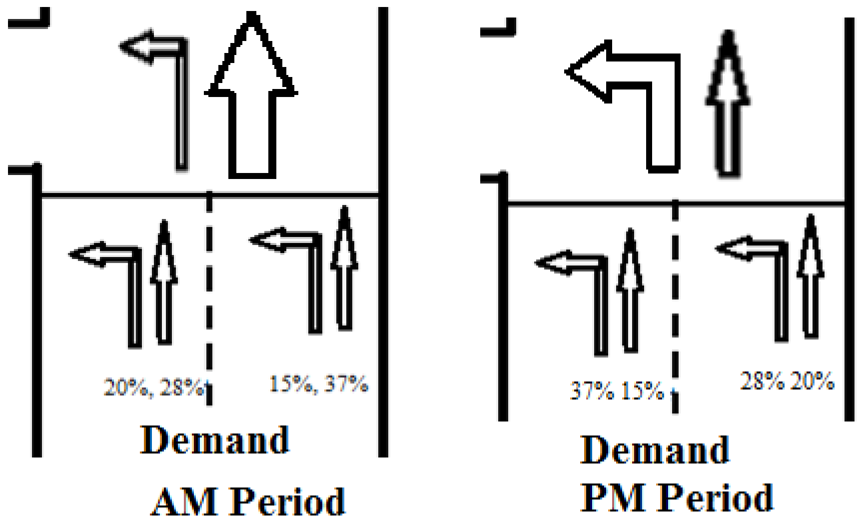

Figure 5.2: Current traffic percentage at AM and PM periods.

A possible application of VMS to dynamically change the lane usage between AM and PM periods, in accordance with the traffic demand, is shown in Figure 5.3.

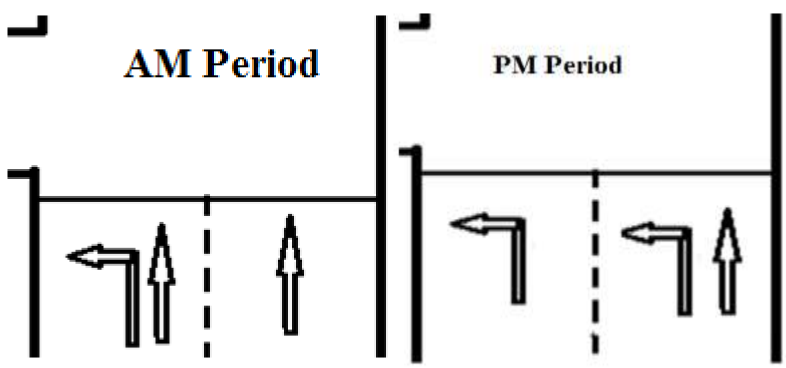

Figure 5.3: Proposed VMS lane usage at AM and PM periods.

It is expected that activating the VMS board before such signalized intersection and advising drivers on each lane usage will have the 8% response from the drivers that was found from the study. This means that the 15% will be reduced to 7%. And keeping in mind that drivers will position their vehicles in the shorter queue lane, it is expected that the same 8% will be shifted from the left to the right lane in the AM period and from the right to the left lane in the PM period, as shown in Figure 5.4.

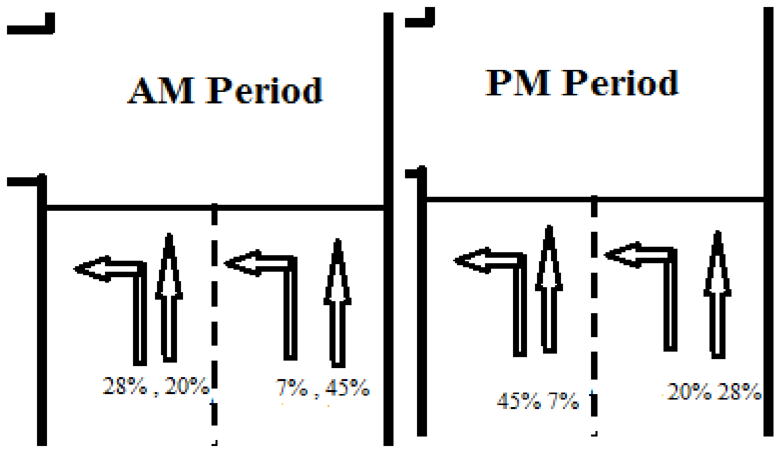

Figure 5.4: VMS impact on traffic percentage at AM and PM periods.

In case the VMS is used with some kind of enforcement at the intersection (like Saher), forcing the drivers to follow the displayed VMS message, the traffic percentage during AM and PM peak hour can be presented as shown in Figure 5.5.

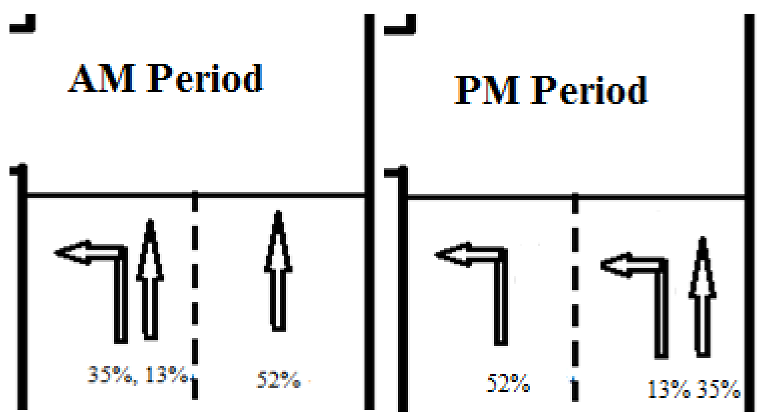

Figure 5.5: Traffic percentage at AM and PM periods using VMS with enforcement.

The above three situations were evaluated using ARENA simulation software. Figure 5.6 shows the dynamic lane usage simulation model.

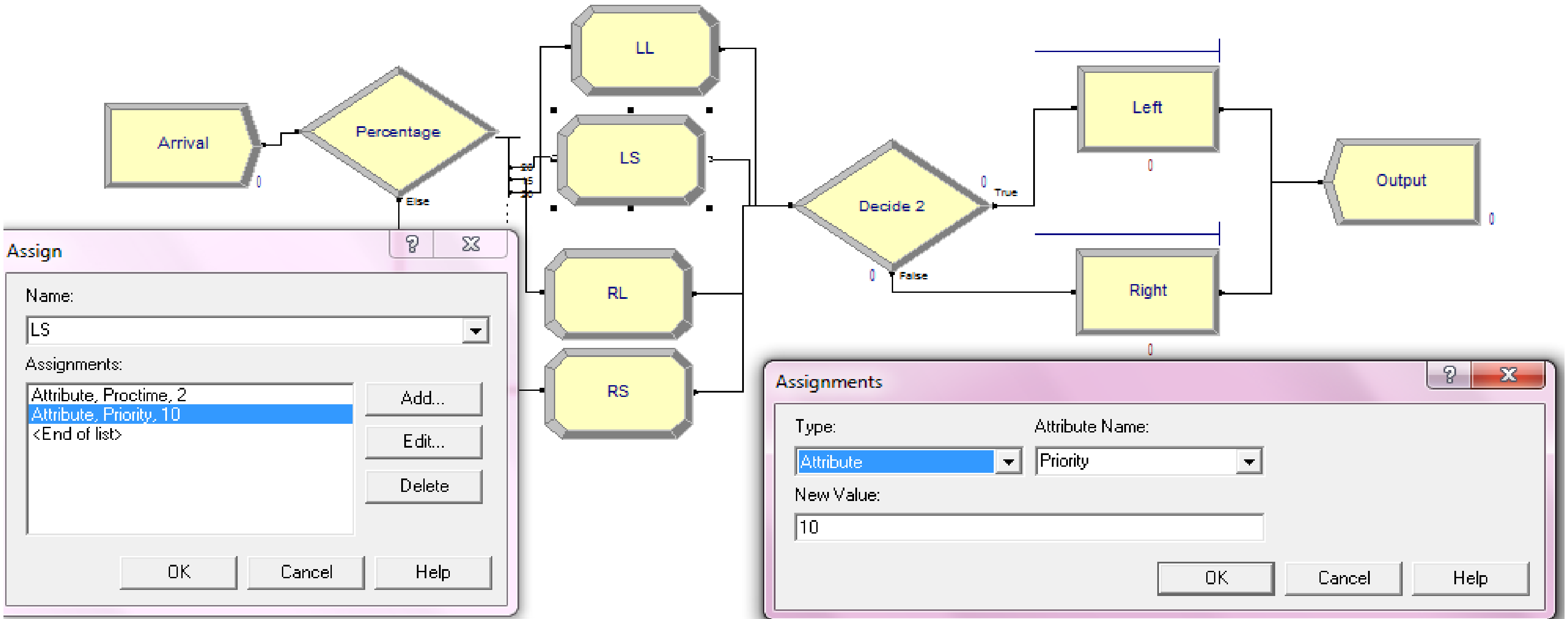

Figure 5.6: Dynamic lane usage simulation model.

The comparison includes the effect of the current local drivers' behavior, VMS message, and achieving fully controlled situation in both AM and PM peak periods. The results are summarized in Tables 5.1 and 5.2.

Table 5.1: Dynamic lane usage evaluation at AM peak period.

Measure (sec/veh) / Situation		Current	With VMS	Enforcement
Average time spent in the system		0.182 (4.87)*	0.177 (4.23)	0.173 (3.94)
Average waiting time in the queue	Right lane	0.204 (3.87)	0.188 (2.96)	0.183 (2.88)
	Left lane	0.158 (3.60)	0.167 (3.23)	0.162 (2.74)

* ( ) Maximum time.

Table 5.2: Dynamic lane usage evaluation at PM peak period.

Measure (sec/veh) / Situation		Current	With VMS	Enforcement
Average time spent in the system		0.176 (3.78)*	0.174 (4.23)	0.172 (4.23)
Average waiting time in the queue	Right lane	0.175 (2.78)	0.161 (3.21)	0.156 (2.94)
	Left lane	0.176 (2.55)	0.186 (3.23)	0.189 (3.23)

* ( ) Maximum time.

Tables 5.1 and 5.2 clearly indicate that the total traffic and queue time were enhanced (reduced) in both peak periods due to VMS usage, and it could be further enhanced if this usage is covered with some kind of enforcement.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study aimed to determine the impact of using VMS messages in Al-Khobar City in Saudi Arabia. The study followed two approaches to evaluate the drivers' response to VMS. Drivers interviews in the study area were conducted, and traffic diversion due to on-site VMS board displayed diverted message to drivers was monitored.

6.2 Conclusions

This study followed two approaches for evaluating the drivers' response to VMS. The first approach depended on interviews with drivers to explore their intended response to VMS. The second approach depended on conducting a field experiment in which the response of drivers to VMS was observed and assessed.

The interview indicated that about one-third of the drivers were never exposed to the VMS technology. Around 82% of the interviewed drivers indicated that they had positive attitude toward VMS. On average, 77% of the drivers reveled that they will alter their travel route in response to VMS. This percentage is within the range of the international studies.

Drivers felt that VMS can improve traffic operation and safety, especially for VMS disseminating information related to accidents, congestion, and roadwork activities. Other messages related to weather or special events did not have such positive response. There is no statistical significant relation between drivers' characteristics (nationality, native language, and driving experience) and response to messages related to accidents, congestion and roadwork activities.

Age on the other hand had an effect on messages related to roadwork activities. Young drivers had statistically less response to messages related to roadwork activities.

Other messages related to adverse weather and special events messages have different relation with drivers' characteristics. Analysis of such messages indicated that local drivers are expected to negatively respond to VMS compared to expatriate drivers. Also, young drivers are expected to have more negative response to VMS than old drivers. Drivers with less driving experience are expected to have more positive response to VMS. Other characteristics such as educational level and type of vehicles have no significant effect on drivers' response to any VMS messages.

The results from the field experiment indicated that VMS affect the behavior of drivers. Traffic counts showed that VMS is statistically effective in rerouting traffic, in congestion conditions. This was obvious when turning traffic exceed 300 vehicles. The VMS was able to increase the percentage of turning traffic by 3-8% during congestion periods on Wednesday and Thursday. This effect seems to be in agreement with previous international studies.

The results of this study hinted to possible economic benefits of VMS in terms of reduction in delay, stops, and fuel consumption.

The effect of VMS is expected to grow in the future when it is introduced to the drivers through professional publicity campaign.

The study showed that the drivers who exit the studied arterial in response to VMS represents only 7 percent of the number of drivers expected to divert from the results of the interviews. The possibility of using VMS as a tool for dynamically lane assignment at signalized intersection 'which was indicated through ARENA simulation proved to be quite promising.

6.3 Recommendations

- It is recommended to adopt this technique and implement it for traffic information in the study area.

- It is recommended to start educating this type of drivers in the driving schools about the importance and efficiency of VMS.

- Authorities are encouraged to start educating the public about the purpose of VMS and its interpretation.

- It is suggested to study the effect of the VMS content such as accident ahead or roadwork activities on the degree of drivers' response.

- The results of this study are specific for one location and might not be applicable to other locations. So, it is recommended to conduct additional field studies to evaluate the message effectiveness in terms of road users' response and other type of messages in other locations.

- It was concluded that there is a strong correlation between the VMS message type and drivers' response, so it is suggested to study the message content as an important control factor for improving traffic efficiency.

- The study indicated (as expected from the literature) that drivers behavior in the field is different from what they declared to do. Usually, the response in the field is much less that what drivers claimed in the interviews. Therefore, interviews results should be treated with some caution, because they are more optimistic and relay on estimation.

- It is recommended to conduct a real field study in dynamic lane assignment to support the benefits observed through simulation.
- It is recommended to introduce VMS techniques to the drivers through prior proper publicity campaign.

APPENDICES

APPENDIX A

INTERVIEW QUESTIONS

Dear Driver

This study aims to examine drivers response to variable message signs, and to put some recommendations of using such signs in Saudi Arabia. This survey aim for research purposes only. The information will be kept confidential and will not be given to any other party.

Part 1: Personal Information:

Nationality: Driving Experience:( ) years) Age:( )

1- Native language:

□ Arabic □ English □ Others

2- What is the highest educational level you have completed?

□ Elementary school or less □ High school □ College or more

3- Can you read basic Arabic words like (أمامك حادث)?

□ Yes □ With Difficulty □ No

4- Can you read basic English words like (Reduce Speed) ?

□ Yes □ With Difficulty □ No

5- Are you familiar with surrounding routes ?

□ Yes □ somewhat familiar □ No

6- What kind of car you drive?

□ Small car Driver (Private, Taxi, Van, Pickup) □ Heavy vehicle Driver (Truck, Bus)

□ Other(…………......)

Part 2: Knowledge and Perception of Variable Message Signs:

1. In your opinion, how important is it to notify the public about highway travel conditions such as congestion, sandy weather, accidents, and construction delays**:**
□ very important □somewhat important □not important □no opinion

2. In your opinion, is it efficient to provide information on traffic conditions through radio, electronic signs, etc
□ very efficient □somewhat efficient □not efficient □no opinion

3. Are you familiar with what variable message signs are?
□ never heard of them □ Heard but never seen them
□ somewhat familiar □ very familiar

Now that you know a little bit about Variable Message Signs (VMS) after describing it by the work team, please answer the following questions.

4. What is the effect of VMS on traffic safety (accident reduction) ?

□ do nothing for safety □somewhat enhance safety
□ highly improve safety □ no opinion

5. Do you think that VMS will help in saving driving time ?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

6. Do you think that VMS will help in reducing stress caused by driving

□ do nothing □ somewhat reduction
□highly reduction □ no opinion

7. Will you trust the traffic information provided by VMS

□ not trust □ somewhat trust
□highly trust □no opinion

8. Do you find it useful if VMS displayed that there is an accident affecting traffic or causing congestion ?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

9. Do you find it useful if VMS displayed current adverse weather information?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

10. Do you find it useful if VMS displayed that there are current or future roadwork?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

11. Do you find it useful if VMS displayed special event information (fairs, sporting events, natural disasters)?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

12. Do you find it useful if VMS displayed recommended alternate routes?

□ not helpful □ somewhat helpful
□highly helpful □no opinion

13. How easy do you think to see and read the messages on the portable variable message signs that are placed on trailers along side the road?

□ very difficult □somewhat difficult
□very easy □no opinion

Part 3: Driver Response to Variable Message Signs:

Now assume a VMS is fixed and activated in your route, answer the following:

1. Would you adjust your travel route due to traffic or travel time information that is provided on VMS?

□ never □rarely
□ usually □always

2. Would you adjust your travel route if a VMS provided that there is an accident ahead?

□ never □rarely
□ usually □always

3.Would you adjust your travel route if a VMS provided an adverse weather information?

□ never □rarely
□ usually □always

4.Would you adjust your travel route if a VMS provided that there is roadwork ahead?

□ never □rarely
□ usually □always

5.Would you adjust your travel route if a VMS provided that there is traffic congestion ahead?

□ never □rarely
□ usually □always

6.Would you adjust your travel route if a VMS provided that there is special event (fairs, sporting events, natural disasters) ahead?

□ never □rarely
□ usually □always

7.What are the reasons that you would choose not to adjust your travel route (click if more than one reason)?

□ you are afraid that you will get lost if you deviate from the planned route.
□ you don't know the alternate routes.
□ you don't feel safe driving in unfamiliar areas.
□ you don't trust that the information provided on the signs is accurate

APPENDIX B

NOT SIGNIFICANT RELATIONS FROM INTERVIEWS

Legend (Key)

X1 Nationality
X2 Native language
X3 Age
X4 Driving Experience
X5 Educational level
X6 Ability to read basic Arabic words
X7 Ability to read basic English words
X8 Familiarity with surrounding routes
X9 Type of vehicle
X10 importance to inform drivers about traffic condition
X11 efficiency of providing traffic information through VMS
X12 familiarity with variable message signs
X13 effect of VMS on traffic safety
X14 effect of VMS in saving driving time
X15 effect of VMS in reducing driving stress
X16 trust the traffic information provided by VMS
X17 usefulness of accident/congestion information through VMS
X18 usefulness of weather information through VMS
X10 usefulness of roadwork information through VMS
X20 usefulness of special events information through VMS
X21 usefulness of alternative route information through VMS
X22 difficulty to see and read portable VMS
X23 route adjustment due to traffic information
X24 route adjustment due to accident information
X25 route adjustment due to weather information
X26 route adjustment due to road work information
X27 route adjustment due to congestion information
X28 route adjustment due to special event information

Tabulated statistics: x1, x12

Rows: x1   Columns: x12

	1	2	3	4	All
1	23	24	50	25	122
	17.57	25.38	50.75	28.30	122.00
	1.6796	0.0746	0.0111	0.3857	*
2	6	19	31	21	77
	11.09	16.02	32.03	17.86	77.00
	2.3348	0.5560	0.0332	0.5505	*
3	7	9	23	12	51
	7.34	10.61	21.22	11.83	51.00
	0.0161	0.2437	0.1500	0.0024	*
All	36	52	104	58	250
	36.00	52.00	104.00	58.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 6.038, DF = 6, P-Value = 0.419
Likelihood Ratio Chi-Square = 6.325, DF = 6, P-Value = 0.388

Tabulated statistics: x1, x15

Rows: x1   Columns: x15

	1	2	3	4	All
1	9	59	43	11	122
	7.81	54.66	49.29	10.25	122.00
	0.1820	0.3453	0.8022	0.0552	*
2	4	33	36	4	77
	4.93	34.50	31.11	6.47	77.00
	0.1748	0.0649	0.7693	0.9417	*
3	3	20	22	6	51
	3.26	22.85	20.60	4.28	51.00
	0.0214	0.3550	0.0946	0.6874	*
All	16	112	101	21	250
	16.00	112.00	101.00	21.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 4.494, DF = 6, P-Value = 0.610
Likelihood Ratio Chi-Square = 4.574, DF = 6, P-Value = 0.599

* NOTE * 3 cells with expected counts less than 5

Tabulated statistics: x1, x17

Rows: x1   Columns: x17

	1	2	3	4	All
1	8	28	77	9	122
	6.83	23.91	80.52	10.74	122.00
	0.1997	0.6989	0.1539	0.2807	*
2	5	9	55	8	77
	4.31	15.09	50.82	6.78	77.00
	0.1098	2.4591	0.3438	0.2211	*
3	1	12	33	5	51
	2.86	10.00	33.66	4.49	51.00
	1.2061	0.4018	0.0129	0.0584	*
All	14	49	165	22	250
	14.00	49.00	165.00	22.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 6.146, DF = 6, P-Value = 0.407
Likelihood Ratio Chi-Square = 6.892, DF = 6, P-Value = 0.331

Tabulated statistics: x1, x20

Rows: x1   Columns: x20

	1	2	3	4	All
1	23	40	51	8	122
	23.91	39.04	52.22	6.83	122.00
	0.0348	0.0236	0.0283	0.1997	*
2	18	27	28	4	77
	15.09	24.64	32.96	4.31	77.00
	0.5603	0.2260	0.7453	0.0226	*
3	8	13	28	2	51
	10.00	16.32	21.83	2.86	51.00
	0.3986	0.6754	1.7452	0.2566	*
All	49	80	107	14	250
	49.00	80.00	107.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 4.916, DF = 6, P-Value = 0.555
Likelihood Ratio Chi-Square = 4.874, DF = 6, P-Value = 0.560

Tabulated statistics: x1, x23

Rows: x1   Columns: x23

	1	2	3	4	All
1	10	23	64	25	122
	7.32	20.01	62.95	31.72	122.00
	0.9812	0.4474	0.0174	1.4237	*
2	2	12	41	22	77
	4.62	12.63	39.73	20.02	77.00
	1.4858	0.0312	0.0405	0.1958	*
3	3	6	24	18	51
	3.06	8.36	26.32	13.26	51.00
	0.0012	0.6682	0.2038	1.6944	*
All	15	41	129	65	250
	15.00	41.00	129.00	65.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 7.191, DF = 6, P-Value = 0.304
Likelihood Ratio Chi-Square = 7.488, DF = 6, P-Value = 0.278

Tabulated statistics: x1, x27

Rows: x1   Columns: x27

	1	2	3	4	Missing	All
1	5	15	43	59	0	122
	5.39	16.66	44.59	55.37	*	122.00
	0.0282	0.1651	0.0564	0.2386	*	*
2	6	10	31	30	0	77
	3.40	10.51	28.14	34.94	*	77.00
	1.9848	0.0251	0.2906	0.6994	*	*
3	0	9	17	24	1	50
	2.21	6.83	18.27	22.69	*	50.00
	2.2088	0.6914	0.0887	0.0755	*	*
All	11	34	91	113	*	249
	11.00	34.00	91.00	113.00	*	249.00
	*	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 6.553, DF = 6, P-Value = 0.364
Likelihood Ratio Chi-Square = 8.356, DF = 6, P-Value = 0.213

Tabulated statistics: x2, x12

Rows: x2   Columns: x12

	1	2	3	4	All
1	29	43	80	46	198
	28.51	41.18	82.37	45.94	198.00
	0.008352	0.080076	0.068078	0.000089	*
2	7	9	24	12	52
	7.49	10.82	21.63	12.06	52.00
	0.031803	0.304905	0.259219	0.000340	*
All	36	52	104	58	250
	36.00	52.00	104.00	58.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 0.753, DF = 3, P-Value = 0.861
Likelihood Ratio Chi-Square = 0.763, DF = 3, P-Value = 0.858

Tabulated statistics: x2, x13

Rows: x2   Columns: x13

	1	2	3	4	All
1	7	67	109	15	198
	7.13	65.74	112.46	12.67	198.00
	0.00230	0.02430	0.10669	0.42768	*
2	2	16	33	1	52
	1.87	17.26	29.54	3.33	52.00
	0.00875	0.09254	0.40626	1.62848	*
All	9	83	142	16	250
	9.00	83.00	142.00	16.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 2.697, DF = 3, P-Value = 0.441
Likelihood Ratio Chi-Square = 3.284, DF = 3, P-Value = 0.350

Tabulated statistics: x2, x15

Rows: x2   Columns: x15

	1	2	3	4	All
1	13	92	78	15	198
	12.67	88.70	79.99	16.63	198.00
	0.00849	0.12247	0.04961	0.16014	*
2	3	20	23	6	52
	3.33	23.30	21.01	4.37	52.00
	0.03233	0.46633	0.18888	0.60976	*
All	16	112	101	21	250
	16.00	112.00	101.00	21.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 1.638, DF = 3, P-Value = 0.651
Likelihood Ratio Chi-Square = 1.597, DF = 3, P-Value = 0.660

Tabulated statistics: x2, x17

Rows: x2   Columns: x17

	1	2	3	4	All
1	13	37	131	17	198
	11.09	38.81	130.68	17.42	198.00
	0.32970	0.08423	0.00078	0.01032	*
2	1	12	34	5	52
	2.91	10.19	34.32	4.58	52.00
	1.25541	0.32073	0.00298	0.03929	*
All	14	49	165	22	250
	14.00	49.00	165.00	22.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 2.043, DF = 3, P-Value = 0.563
Likelihood Ratio Chi-Square = 2.440, DF = 3, P-Value = 0.486

Tabulated statistics: x2, x18

Rows: x2   Columns: x18

	1	2	3	4	All
1	7	67	113	11	198
	8.71	63.36	114.84	11.09	198.00
	0.33643	0.20912	0.02948	0.00070	*
2	4	13	32	3	52
	2.29	16.64	30.16	2.91	52.00
	1.28101	0.79625	0.11225	0.00266	*
All	11	80	145	14	250
	11.00	80.00	145.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 2.768, DF = 3, P-Value = 0.429
Likelihood Ratio Chi-Square = 2.616, DF = 3, P-Value = 0.455

Tabulated statistics: x2, x19

Rows: x2   Columns: x19

	1	2	3	4	All
1	5	34	151	8	198
	4.75	38.02	147.31	7.92	198.00
	0.01294	0.42425	0.09233	0.00081	*
2	1	14	35	2	52
	1.25	9.98	38.69	2.08	52.00
	0.04928	1.61541	0.35156	0.00308	*
All	6	48	186	10	250
	6.00	48.00	186.00	10.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 2.550, DF = 3, P-Value = 0.466
Likelihood Ratio Chi-Square = 2.399, DF = 3, P-Value = 0.494

Tabulated statistics: x2, x20

Rows: x2   Columns: x20

	1	2	3	4	All
1	41	66	79	12	198
	38.81	63.36	84.74	11.09	198.00
	0.1238	0.1100	0.3893	0.0750	*
2	8	14	28	2	52
	10.19	16.64	22.26	2.91	52.00
	0.4714	0.4188	1.4825	0.2856	*
All	49	80	107	14	250
	49.00	80.00	107.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 3.357, DF = 3, P-Value = 0.340
Likelihood Ratio Chi-Square = 3.344, DF = 3, P-Value = 0.342

Tabulated statistics: x2, x23

Rows: x2   Columns: x23

	1	2	3	4	All
1	12	35	104	47	198
	11.88	32.47	102.17	51.48	198.00
	0.00121	0.19681	0.03285	0.38987	*
2	3	6	25	18	52
	3.12	8.53	26.83	13.52	52.00
	0.00462	0.74939	0.12508	1.48450	*
All	15	41	129	65	250
	15.00	41.00	129.00	65.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 2.984, DF = 3, P-Value = 0.394
Likelihood Ratio Chi-Square = 2.940, DF = 3, P-Value = 0.401

Tabulated statistics: x2, x26

```
Rows: x2   Columns: x26

            1       2       3       4     All

1           6      28      82      82     198
         6.34   30.10   75.24   86.33  198.00
       0.0178  0.1460  0.6074  0.2170       *

2           2      10      13      27      52
         1.66    7.90   19.76   22.67   52.00
       0.0678  0.5558  2.3126  0.8262       *

All         8      38      95     109     250
         8.00   38.00   95.00  109.00  250.00
            *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 4.751, DF = 3, P-Value = 0.191
Likelihood Ratio Chi-Square = 4.966, DF = 3, P-Value = 0.174
```

Tabulated statistics: x2, x27

```
Rows: x2   Columns: x27

            1       2       3       4  Missing     All

1          11      25      74      88        0     198
         8.75   27.04   72.36   89.86        *  198.00
       0.5803  0.1533  0.0371  0.0383        *       *

2           0       9      17      25        1      51
         2.25    6.96   18.64   23.14        *   51.00
       2.2530  0.5953  0.1440  0.1487        *       *

All        11      34      91     113        *     249
        11.00   34.00   91.00  113.00        *  249.00
            *       *       *       *        *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 3.950, DF = 3, P-Value = 0.267
Likelihood Ratio Chi-Square = 6.113, DF = 3, P-Value = 0.106
```

Tabulated statistics: x3, x13

Rows: x3   Columns: x13

	1	2	3	4	All
1	2	15	26	1	44
	1.58	14.61	24.99	2.82	44.00
	0.1093	0.0105	0.0407	1.1711	*
2	5	50	76	11	142
	5.11	47.14	80.66	9.09	142.00
	0.0025	0.1730	0.2688	0.4023	*
3	2	10	27	3	42
	1.51	13.94	23.86	2.69	42.00
	0.1575	1.1155	0.4144	0.0362	*
4	0	8	13	1	22
	0.79	7.30	12.50	1.41	22.00
	0.7920	0.0663	0.0203	0.1182	*
All	9	83	142	16	250
	9.00	83.00	142.00	16.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 4.899, DF = 9
Likelihood Ratio Chi-Square = 6.149, DF = 9

Tabulated statistics: x3, x16

Rows: x3   Columns: x16

	1	2	3	4	All
1	3	21	13	7	44
	2.29	18.30	19.01	4.40	44.00
	0.2216	0.3971	1.8990	1.5364	*
2	9	59	64	10	142
	7.38	59.07	61.34	14.20	142.00
	0.3537	0.0001	0.1150	1.2423	*
3	1	13	24	4	42
	2.18	17.47	18.14	4.20	42.00
	0.6419	1.1446	1.8900	0.0095	*
4	0	11	7	4	22
	1.14	9.15	9.50	2.20	22.00
	1.1440	0.3732	0.6597	1.4727	*
All	13	104	108	25	250
	13.00	104.00	108.00	25.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square
Pearson Chi-Square = 13.101, DF = 9, P-Value = 0.158
Likelihood Ratio Chi-Square = 14.184, DF = 9, P-Value = 0.116

Tabulated statistics: x3, x17

Rows: x3   Columns: x17

	1	2	3	4	All
1	3	9	31	1	44
	2.46	8.62	29.04	3.87	44.00
	0.1166	0.0164	0.1323	2.1303	*
2	7	29	91	15	142
	7.95	27.83	93.72	12.50	142.00
	0.1140	0.0490	0.0789	0.5018	*
3	2	7	32	1	42
	2.35	8.23	27.72	3.70	42.00
	0.0527	0.1844	0.6608	1.9666	*
4	2	4	11	5	22
	1.23	4.31	14.52	1.94	22.00
	0.4788	0.0226	0.8533	4.8492	*
All	14	49	165	22	250
	14.00	49.00	165.00	22.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 12.208, DF = 9, P-Value = 0.202
Likelihood Ratio Chi-Square = 12.383, DF = 9, P-Value = 0.193

Tabulated statistics: x3, x18

Rows: x3   Columns: x18

	1	2	3	4	All
1	2	10	32	0	44
	1.94	14.08	25.52	2.46	44.00
	0.0021	1.1823	1.6454	2.4640	*
2	7	50	75	10	142
	6.25	45.44	82.36	7.95	142.00
	0.0905	0.4576	0.6577	0.5275	*
3	2	12	25	3	42
	1.85	13.44	24.36	2.35	42.00
	0.0125	0.1543	0.0168	0.1785	*
4	0	8	13	1	22
	0.97	7.04	12.76	1.23	22.00
	0.9680	0.1309	0.0045	0.0437	*
All	11	80	145	14	250
	11.00	80.00	145.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square
Pearson Chi-Square = 8.536, DF = 9
Likelihood Ratio Chi-Square = 11.929, DF = 9

Tabulated statistics: x3, x19

Rows: x3   Columns: x19

	1	2	3	4	All
1	1	12	31	0	44
	1.06	8.45	32.74	1.76	44.00
	0.0030	1.4935	0.0921	1.7600	*
2	5	27	102	8	142
	3.41	27.26	105.65	5.68	142.00
	0.7437	0.0026	0.1260	0.9476	*
3	0	7	33	2	42
	1.01	8.06	31.25	1.68	42.00
	1.0080	0.1404	0.0982	0.0610	*
4	0	2	20	0	22
	0.53	4.22	16.37	0.88	22.00
	0.5280	1.1710	0.8059	0.8800	*
All	6	48	186	10	250
	6.00	48.00	186.00	10.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 9.861, DF = 9
Likelihood Ratio Chi-Square = 13.898, DF = 9

Tabulated statistics: x3, x20

Rows: x3   Columns: x20

	1	2	3	4	All
1	11	15	18	0	44
	8.62	14.08	18.83	2.46	44.00
	0.6546	0.0601	0.0368	2.4640	*
2	23	45	63	11	142
	27.83	45.44	60.78	7.95	142.00
	0.8389	0.0043	0.0814	1.1683	*
3	9	12	18	3	42
	8.23	13.44	17.98	2.35	42.00
	0.0717	0.1543	0.0000	0.1785	*
4	6	8	8	0	22
	4.31	7.04	9.42	1.23	22.00
	0.6608	0.1309	0.2129	1.2320	*
All	49	80	107	14	250
	49.00	80.00	107.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 7.949, DF = 9, P-Value = 0.539
Likelihood Ratio Chi-Square = 11.441, DF = 9, P-Value = 0.247

Tabulated statistics: x3, x21

```
Rows: x3   Columns: x21

            1       2       3       4     All

1           3       8      32       1      44
         1.58    9.50   29.22    3.70   44.00
       1.2658  0.2380  0.2653  1.9666       *

2           4      30      91      17     142
         5.11   30.67   94.29   11.93  142.00
       0.2419  0.0147  0.1147  2.1567       *

3           2      10      28       2      42
         1.51    9.07   27.89    3.53   42.00
       0.1575  0.0949  0.0004  0.6618       *

4           0       6      15       1      22
         0.79    4.75   14.61    1.85   22.00
       0.7920  0.3278  0.0105  0.3891       *

All         9      54     166      21     250
         9.00   54.00  166.00   21.00  250.00
            *       *       *       *       *
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 8.698, DF = 9
Likelihood Ratio Chi-Square = 9.967, DF = 9
```

Tabulated statistics: x3, x22

```
Rows: x3   Columns: x22

            1       2       3       4     All

1           9      20      11       4      44
         5.10   19.36   11.97    7.57   44.00
       2.9739  0.0212  0.0783  1.6822       *

2          11      66      39      26     142
        16.47   62.48   38.62   24.42  142.00
       1.8178  0.1983  0.0037  0.1017       *

3           5      14      14       9      42
         4.87   18.48   11.42    7.22   42.00
       0.0034  1.0861  0.5809  0.4366       *

4           4      10       4       4      22
         2.55    9.68    5.98    3.78   22.00
       0.8216  0.0106  0.6578  0.0123       *

All        29     110      68      43     250
        29.00  110.00   68.00   43.00  250.00
            *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square
Pearson Chi-Square = 10.486, DF = 9, P-Value = 0.313
Likelihood Ratio Chi-Square = 10.516, DF = 9, P-Value = 0.310
```

Tabulated statistics: x3, x24

Rows: x3   Columns: x24

	1	2	3	4	All
1	0	4	12	28	44
	1.76	5.28	16.19	20.77	44.00
	1.76000	0.31030	1.08528	2.51839	*
2	8	17	57	60	142
	5.68	17.04	52.26	67.02	142.00
	0.94761	0.00009	0.43068	0.73610	*
3	2	5	15	20	42
	1.68	5.04	15.46	19.82	42.00
	0.06095	0.00032	0.01345	0.00156	*
4	0	4	8	10	22
	0.88	2.64	8.10	10.38	22.00
	0.88000	0.70061	0.00114	0.01420	*
All	10	30	92	118	250
	10.00	30.00	92.00	118.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 9.461, DF = 9
Likelihood Ratio Chi-Square = 11.795, DF = 9

Tabulated statistics: x3, x26

Rows: x3   Columns: x26

	1	2	3	4	All
1	1	14	7	22	44
	1.41	6.69	16.72	19.18	44.00
	0.1182	7.9942	5.6506	0.4134	*
2	5	16	64	57	142
	4.54	21.58	53.96	61.91	142.00
	0.0458	1.4446	1.8681	0.3897	*
3	1	6	14	21	42
	1.34	6.38	15.96	18.31	42.00
	0.0880	0.0231	0.2407	0.3946	*
4	1	2	10	9	22
	0.70	3.34	8.36	9.59	22.00
	0.1245	0.5402	0.3217	0.0365	*
All	8	38	95	109	250
	8.00	38.00	95.00	109.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square
Pearson Chi-Square = 19.694, DF = 9
Likelihood Ratio Chi-Square = 19.462, DF = 9

Tabulated statistics: x3, x27

Rows: x3   Columns: x27

	1	2	3	4	Missing	All
1	3	7	10	24	0	44
	1.94	6.01	16.08	19.97	*	44.00
	0.5739	0.1638	2.2991	0.8142	*	*
2	5	16	56	64	1	141
	6.23	19.25	51.53	63.99	*	141.00
	0.2425	0.5496	0.3877	0.0000	*	*
3	2	9	14	17	0	42
	1.86	5.73	15.35	19.06	*	42.00
	0.0113	1.8589	0.1186	0.2227	*	*
4	1	2	11	8	0	22
	0.97	3.00	8.04	9.98	*	22.00
	0.0008	0.3356	1.0896	0.3942	*	*
All	11	34	91	113	*	249
	11.00	34.00	91.00	113.00	*	249.00
	*	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 9.063, DF = 9
Likelihood Ratio Chi-Square = 9.019, DF = 9

Tabulated statistics: x3, x11_1

Rows: x3   Columns: x11_1

	1	2	All
1	29	15	44
	24.46	19.54	44.00
	0.8410	1.0532	*
2	77	65	142
	78.95	63.05	142.00
	0.0483	0.0604	*
3	19	23	42
	23.35	18.65	42.00
	0.8111	1.0157	*
4	14	8	22
	12.23	9.77	22.00
	0.2555	0.3200	*
All	139	111	250
	139.00	111.00	250.00
	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 4.405, DF = 3, P-Value = 0.221
Likelihood Ratio Chi-Square = 4.444, DF = 3, P-Value = 0.217

Tabulated statistics: x4, x12

Rows: x4   Columns: x12

	1	2	3	4	All
1	9	21	31	15	76
	10.94	15.81	31.62	17.63	76.00
	0.3453	1.7053	0.0120	0.3929	*
2	18	15	45	19	97
	13.97	20.18	40.35	22.50	97.00
	1.1639	1.3279	0.5354	0.5456	*
3	2	8	13	13	36
	5.18	7.49	14.98	8.35	36.00
	1.9556	0.0350	0.2607	2.5867	*
4	7	8	15	11	41
	5.90	8.53	17.06	9.51	41.00
	0.2035	0.0327	0.2478	0.2328	*
All	36	52	104	58	250
	36.00	52.00	104.00	58.00	250.00
	*	*	*	*	*

```
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 11.583, DF = 9, P-Value = 0.238
Likelihood Ratio Chi-Square = 11.733, DF = 9, P-Value = 0.229
```

Tabulated statistics: x4, x13

Rows: x4   Columns: x13

	1	2	3	4	All
1	2	22	50	2	76
	2.74	25.23	43.17	4.86	76.00
	0.1980	0.4140	1.0813	1.6864	*
2	5	36	48	8	97
	3.49	32.20	55.10	6.21	97.00
	0.6512	0.4474	0.9139	0.5173	*
3	1	13	20	2	36
	1.30	11.95	20.45	2.30	36.00
	0.0676	0.0919	0.0098	0.0401	*
4	1	12	24	4	41
	1.48	13.61	23.29	2.62	41.00
	0.1535	0.1909	0.0218	0.7216	*
All	9	83	142	16	250
	9.00	83.00	142.00	16.00	250.00
	*	*	*	*	*

```
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square
Pearson Chi-Square = 7.207, DF = 9, P-Value = 0.616
Likelihood Ratio Chi-Square = 7.516, DF = 9, P-Value = 0.584
```

Tabulated statistics: x4, x16

Rows: x4   Columns: x16

	1	2	3	4	All
1	5	31	31	9	76
	3.95	31.62	32.83	7.60	76.00
	0.2779	0.0120	0.1022	0.2579	*
2	6	37	48	6	97
	5.04	40.35	41.90	9.70	97.00
	0.1812	0.2784	0.8868	1.4113	*
3	2	12	17	5	36
	1.87	14.98	15.55	3.60	36.00
	0.0088	0.5914	0.1348	0.5444	*
4	0	24	12	5	41
	2.13	17.06	17.71	4.10	41.00
	2.1320	2.8271	1.8421	0.1976	*
All	13	104	108	25	250
	13.00	104.00	108.00	25.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 11.686, DF = 9, P-Value = 0.232
Likelihood Ratio Chi-Square = 13.850, DF = 9, P-Value = 0.128

Tabulated statistics: x4, x17

Rows: x4   Columns: x17

	1	2	3	4	All
1	5	15	52	4	76
	4.26	14.90	50.16	6.69	76.00
	0.13006	0.00073	0.06750	1.08034	*
2	5	22	59	11	97
	5.43	19.01	64.02	8.54	97.00
	0.03436	0.46961	0.39363	0.71126	*
3	1	5	27	3	36
	2.02	7.06	23.76	3.17	36.00
	0.51203	0.59908	0.44182	0.00891	*
4	3	7	27	4	41
	2.30	8.04	27.06	3.61	41.00
	0.21586	0.13356	0.00013	0.04259	*
All	14	49	165	22	250
	14.00	49.00	165.00	22.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 4.841, DF = 9, P-Value = 0.848
Likelihood Ratio Chi-Square = 5.099, DF = 9, P-Value = 0.826

Tabulated statistics: x4, x19

Rows: x4   Columns: x19

	1	2	3	4	All
1	1	17	57	1	76
	1.82	14.59	56.54	3.04	76.00
	0.3722	0.3974	0.0037	1.3689	*
2	3	17	69	8	97
	2.33	18.62	72.17	3.88	97.00
	0.1940	0.1416	0.1391	4.3748	*
3	1	6	28	1	36
	0.86	6.91	26.78	1.44	36.00
	0.0214	0.1203	0.0552	0.1344	*
4	1	8	32	0	41
	0.98	7.87	30.50	1.64	41.00
	0.0003	0.0021	0.0734	1.6400	*
All	6	48	186	10	250
	6.00	48.00	186.00	10.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 9.039, DF = 9
Likelihood Ratio Chi-Square = 10.191, DF = 9

Tabulated statistics: x4, x20

Rows: x4   Columns: x20

	1	2	3	4	All
1	14	25	35	2	76
	14.90	24.32	32.53	4.26	76.00
	0.0539	0.0190	0.1879	1.1958	*
2	14	29	44	10	97
	19.01	31.04	41.52	5.43	97.00
	1.3213	0.1341	0.1486	3.8414	*
3	9	10	16	1	36
	7.06	11.52	15.41	2.02	36.00
	0.5356	0.2006	0.0227	0.5120	*
4	12	16	12	1	41
	8.04	13.12	17.55	2.30	41.00
	1.9554	0.6322	1.7541	0.7315	*
All	49	80	107	14	250
	49.00	80.00	107.00	14.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square
Pearson Chi-Square = 13.246, DF = 9, P-Value = 0.152
Likelihood Ratio Chi-Square = 13.102, DF = 9, P-Value = 0.158

Tabulated statistics: x4, x22

Rows: x4   Columns: x22

	1	2	3	4	All
1	13	33	19	11	76
	8.82	33.44	20.67	13.07	76.00
	1.9857	0.0058	0.1352	0.3284	*
2	7	43	27	20	97
	11.25	42.68	26.38	16.68	97.00
	1.6068	0.0024	0.0144	0.6591	*
3	2	15	12	7	36
	4.18	15.84	9.79	6.19	36.00
	1.1339	0.0445	0.4979	0.1054	*
4	7	19	10	5	41
	4.76	18.04	11.15	7.05	41.00
	1.0588	0.0511	0.1190	0.5971	*
All	29	110	68	43	250
	29.00	110.00	68.00	43.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 8.345, DF = 9, P-Value = 0.500
Likelihood Ratio Chi-Square = 8.497, DF = 9, P-Value = 0.485

Tabulated statistics: x4, x23

Rows: x4   Columns: x23

	1	2	3	4	All
1	3	15	43	15	76
	4.56	12.46	39.22	19.76	76.00
	0.5337	0.5160	0.3651	1.1466	*
2	8	10	49	30	97
	5.82	15.91	50.05	25.22	97.00
	0.8166	2.1941	0.0221	0.9060	*
3	1	7	17	11	36
	2.16	5.90	18.58	9.36	36.00
	0.6230	0.2035	0.1337	0.2874	*
4	3	9	20	9	41
	2.46	6.72	21.16	10.66	41.00
	0.1185	0.7704	0.0632	0.2585	*
All	15	41	129	65	250
	15.00	41.00	129.00	65.00	250.00
	*	*	*	*	*

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 8.958, DF = 9, P-Value = 0.441
Likelihood Ratio Chi-Square = 9.360, DF = 9, P-Value = 0.405

Tabulated statistics: x4, x24

Rows: x4   Columns: x24

	1	2	3	4	All
1	2	6	26	42	76
	3.04	9.12	27.97	35.87	76.00
	0.3558	1.0674	0.1385	1.0468	*
2	5	14	34	44	97
	3.88	11.64	35.70	45.78	97.00
	0.3233	0.4785	0.0806	0.0695	*
3	1	3	17	15	36
	1.44	4.32	13.25	16.99	36.00
	0.1344	0.4033	1.0626	0.2335	*
4	2	7	15	17	41
	1.64	4.92	15.09	19.35	41.00
	0.0790	0.8793	0.0005	0.2859	*
All	10	30	92	118	250
	10.00	30.00	92.00	118.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 6.639, DF = 9, P-Value = 0.675
Likelihood Ratio Chi-Square = 6.621, DF = 9, P-Value = 0.676

Tabulated statistics: x4, x26

Rows: x4   Columns: x26

	1	2	3	4	All
1	2	16	19	39	76
	2.43	11.55	28.88	33.14	76.00
	0.0767	1.7127	3.3800	1.0377	*
2	3	13	41	40	97
	3.10	14.74	36.86	42.29	97.00
	0.0035	0.2063	0.4650	0.1242	*
3	1	2	18	15	36
	1.15	5.47	13.68	15.70	36.00
	0.0201	2.2030	1.3642	0.0309	*
4	2	7	17	15	41
	1.31	6.23	15.58	17.88	41.00
	0.3608	0.0946	0.1294	0.4627	*
All	8	38	95	109	250
	8.00	38.00	95.00	109.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 11.672, DF = 9, P-Value = 0.232
Likelihood Ratio Chi-Square = 12.460, DF = 9, P-Value = 0.189

Tabulated statistics: x4, x27

Rows: x4   Columns: x27

	1	2	3	4	Missing	All
1	5	10	24	36	1	75
	3.31	10.24	27.41	34.04	*	75.00
	0.8587	0.0057	0.4241	0.1133	*	*
2	4	11	35	47	0	97
	4.29	13.24	35.45	44.02	*	97.00
	0.0190	0.3805	0.0057	0.2017	*	*
3	0	5	14	17	0	36
	1.59	4.92	13.16	16.34	*	36.00
	1.5904	0.0014	0.0541	0.0269	*	*
4	2	8	18	13	0	41
	1.81	5.60	14.98	18.61	*	41.00
	0.0197	1.0302	0.6071	1.6893	*	*
All	11	34	91	113	*	249
	11.00	34.00	91.00	113.00	*	249.00
	*	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 7.028, DF = 9, P-Value = 0.634
Likelihood Ratio Chi-Square = 8.577, DF = 9, P-Value = 0.477

Tabulated statistics: x5, x12

Rows: x5   Columns: x12

	1	2	3	4	All
1	2	6	2	3	13
	1.87	2.70	5.41	3.02	13.00
	0.00875	4.01761	2.14764	0.00008	*
2	19	22	46	26	113
	16.27	23.50	47.01	26.22	113.00
	0.45735	0.09624	0.02161	0.00178	*
3	15	24	56	29	124
	17.86	25.79	51.58	28.77	124.00
	0.45681	0.12451	0.37804	0.00187	*
All	36	52	104	58	250
	36.00	52.00	104.00	58.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 7.712, DF = 6, P-Value = 0.260
Likelihood Ratio Chi-Square = 7.354, DF = 6, P-Value = 0.289

Tabulated statistics: x5, x13

```
Rows: x5   Columns: x13

            1       2       3       4     All

1           0       2      10       1      13
         0.47    4.32    7.38    0.83   13.00
       0.4680  1.2428  0.9268  0.0339       *

2           6      38      58      11     113
         4.07   37.52   64.18    7.23  113.00
       0.9176  0.0062  0.5958  1.9632       *

3           3      43      74       4     124
         4.46   41.17   70.43    7.94  124.00
       0.4801  0.0815  0.1808  1.9521       *

All         9      83     142      16     250
         9.00   83.00  142.00   16.00  250.00
            *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 8.849, DF = 6
Likelihood Ratio Chi-Square = 9.661, DF = 6
```

Tabulated statistics: x5, x14

```
Rows: x5   Columns: x14

             1        2        3        4     All

1            1        4        7        1      13
          1.35     4.73     5.46     1.46   13.00
       0.09164  0.11323  0.43436  0.14281       *

2           15       43       42       13     113
         11.75    41.13    47.46    12.66  113.00
       0.89768  0.08483  0.62814  0.00935       *

3           10       44       56       14     124
         12.90    45.14    52.08    13.89  124.00
       0.65034  0.02859  0.29505  0.00090       *

All         26       91      105       28     250
         26.00    91.00   105.00    28.00  250.00
             *        *        *        *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 3.377, DF = 6, P-Value = 0.760
Likelihood Ratio Chi-Square = 3.374, DF = 6, P-Value = 0.761
```

Tabulated statistics: x5, x15

```
Rows: x5   Columns: x15

             1       2       3       4     All

1            2       2       6       3      13
          0.83    5.82    5.25    1.09   13.00
        1.6397  2.5108  0.1065  3.3338       *

2           10      52      41      10     113
          7.23   50.62   45.65    9.49  113.00
        1.0594  0.0374  0.4740  0.0272       *

3            4      58      54       8     124
          7.94   55.55   50.10   10.42  124.00
        1.9521  0.1079  0.3042  0.5604       *

All         16     112     101      21     250
         16.00  112.00  101.00   21.00  250.00
             *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 12.114, DF = 6
Likelihood Ratio Chi-Square = 11.798, DF = 6
```

Tabulated statistics: x5, x16

```
Rows: x5   Columns: x16

             1       2       3       4     All

1            0       4       7       2      13
          0.68    5.41    5.62    1.30   13.00
        0.6760  0.3666  0.3411  0.3769       *

2            7      52      39      15     113
          5.88   47.01   48.82   11.30  113.00
        0.2150  0.5301  1.9738  1.2115       *

3            6      48      62       8     124
          6.45   51.58   53.57   12.40  124.00
        0.0311  0.2490  1.3273  1.5613       *

All         13     104     108      25     250
         13.00  104.00  108.00   25.00  250.00
             *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 8.860, DF = 6
Likelihood Ratio Chi-Square = 9.665, DF = 6
```

Tabulated statistics: x5, x17

```
Rows: x5   Columns: x17

            1       2       3       4     All

1           0       3       8       2      13
         0.73    2.55    8.58    1.14   13.00
       0.7280  0.0802  0.0392  0.6405       *

2          12      25      63      13     113
         6.33   22.15   74.58    9.94  113.00
       5.0840  0.3673  1.7980  0.9392       *

3           2      21      94       7     124
         6.94   24.30   81.84   10.91  124.00
       3.5200  0.4492  1.8068  1.4025       *

All        14      49     165      22     250
        14.00   49.00  165.00   22.00  250.00
            *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 16.855, DF = 6
Likelihood Ratio Chi-Square = 17.928, DF = 6
```

Tabulated statistics: x5, x18

```
Rows: x5   Columns: x18

            1       2       3       4     All

1           1       6       4       2      13
         0.57    4.16    7.54    0.73   13.00
       0.3203  0.8138  1.6620  2.2225       *

2           4      37      64       8     113
         4.97   36.16   65.54    6.33  113.00
       0.1900  0.0195  0.0362  0.4418       *

3           6      37      77       4     124
         5.46   39.68   71.92    6.94  124.00
       0.0542  0.1810  0.3588  1.2481       *

All        11      80     145      14     250
        11.00   80.00  145.00   14.00  250.00
            *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 7.548, DF = 6
Likelihood Ratio Chi-Square = 7.214, DF = 6
```

Tabulated statistics: x5, x19

```
Rows: x5   Columns: x19

             1       2       3       4     All

1            2       2       8       1      13
          0.31    2.50    9.67    0.52   13.00
        9.1325  0.0986  0.2890  0.4431       *

2            2      28      77       6     113
          2.71   21.70   84.07    4.52  113.00
        0.1869  1.8317  0.5949  0.4846       *

3            2      18     101       3     124
          2.98   23.81   92.26    4.96  124.00
        0.3201  1.4169  0.8288  0.7745       *

All          6      48     186      10     250
          6.00   48.00  186.00   10.00  250.00
             *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 16.402, DF = 6
Likelihood Ratio Chi-Square = 11.368, DF = 6
```

Tabulated statistics: x5, x20

```
Rows: x5   Columns: x20

             1       2       3       4     All

1            2       3       7       1      13
          2.55    4.16    5.56    0.73   13.00
        0.1179  0.3235  0.3706  0.1016       *

2           25      36      44       8     113
         22.15   36.16   48.36    6.33  113.00
        0.3673  0.0007  0.3938  0.4418       *

3           22      41      56       5     124
         24.30   39.68   53.07    6.94  124.00
        0.2184  0.0439  0.1615  0.5442       *

All         49      80     107      14     250
         49.00   80.00  107.00   14.00  250.00
             *       *       *       *       *

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 3.085, DF = 6
Likelihood Ratio Chi-Square = 3.117, DF = 6
```

Tabulated statistics: x5, x21

Rows: x5   Columns: x21

	1	2	3	4	All
1	3	1	7	2	13
	0.47	2.81	8.63	1.09	13.00
	13.699	1.164	0.309	0.755	*
2	5	28	67	13	113
	4.07	24.41	75.03	9.49	113.00
	0.214	0.529	0.860	1.296	*
3	1	25	92	6	124
	4.46	26.78	82.34	10.42	124.00
	2.688	0.119	1.134	1.872	*
All	9	54	166	21	250
	9.00	54.00	166.00	21.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 24.638, DF = 6
Likelihood Ratio Chi-Square = 18.688, DF = 6

Tabulated statistics: x5, x22

Rows: x5   Columns: x22

	1	2	3	4	All
1	3	3	3	4	13
	1.51	5.72	3.54	2.24	13.00
	1.4762	1.2934	0.0812	1.3916	*
2	13	56	29	15	113
	13.11	49.72	30.74	19.44	113.00
	0.0009	0.7932	0.0981	1.0125	*
3	13	51	36	24	124
	14.38	54.56	33.73	21.33	124.00
	0.1332	0.2323	0.1530	0.3348	*
All	29	110	68	43	250
	29.00	110.00	68.00	43.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 7.000, DF = 6, P-Value = 0.321
Likelihood Ratio Chi-Square = 6.730, DF = 6, P-Value = 0.347

Tabulated statistics: x5, x23

Rows: x5   Columns: x23

	1	2	3	4	All
1	2	4	4	3	13
	0.78	2.13	6.71	3.38	13.00
	1.9082	1.6367	1.0932	0.0427	*
2	10	19	57	27	113
	6.78	18.53	58.31	29.38	113.00
	1.5293	0.0118	0.0293	0.1928	*
3	3	18	68	35	124
	7.44	20.34	63.98	32.24	124.00
	2.6497	0.2683	0.2521	0.2363	*
All	15	41	129	65	250
	15.00	41.00	129.00	65.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 9.850, DF = 6
Likelihood Ratio Chi-Square = 9.707, DF = 6

Tabulated statistics: x5, x23

Rows: x5   Columns: x23

	1	2	3	4	All
1	2	4	4	3	13
	0.78	2.13	6.71	3.38	13.00
	1.9082	1.6367	1.0932	0.0427	*
2	10	19	57	27	113
	6.78	18.53	58.31	29.38	113.00
	1.5293	0.0118	0.0293	0.1928	*
3	3	18	68	35	124
	7.44	20.34	63.98	32.24	124.00
	2.6497	0.2683	0.2521	0.2363	*
All	15	41	129	65	250
	15.00	41.00	129.00	65.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 9.850, DF = 6
Likelihood Ratio Chi-Square = 9.707, DF = 6

Tabulated statistics: x5, x24

Rows: x5   Columns: x24

	1	2	3	4	All
1	0	5	2	6	13
	0.52	1.56	4.78	6.14	13.00
	0.52000	7.58564	1.62012	0.00301	*
2	5	13	41	54	113
	4.52	13.56	41.58	53.34	113.00
	0.05097	0.02313	0.00820	0.00827	*
3	5	12	49	58	124
	4.96	14.88	45.63	58.53	124.00
	0.00032	0.55742	0.24858	0.00476	*
All	10	30	92	118	250
	10.00	30.00	92.00	118.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 10.630, DF = 6
Likelihood Ratio Chi-Square = 8.824, DF = 6

Tabulated statistics: x5, x25

Rows: x5   Columns: x25

	1	2	3	4	All
1	3	3	5	2	13
	0.68	3.12	5.30	3.90	13.00
	7.9896	0.0046	0.0174	0.9256	*
2	5	28	43	37	113
	5.88	27.12	46.10	33.90	113.00
	0.1306	0.0286	0.2090	0.2835	*
3	5	29	54	36	124
	6.45	29.76	50.59	37.20	124.00
	0.3252	0.0194	0.2296	0.0387	*
All	13	60	102	75	250
	13.00	60.00	102.00	75.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 10.202, DF = 6
Likelihood Ratio Chi-Square = 6.735, DF = 6

Tabulated statistics: x5, x26

Rows: x5 Columns: x26

	1	2	3	4	All
1	3	2	2	6	13
	0.42	1.98	4.94	5.67	13.00
	16.05062	0.00029	1.74972	0.01945	*
2	2	20	42	49	113
	3.62	17.18	42.94	49.27	113.00
	0.72219	0.46431	0.02058	0.00146	*
3	3	16	51	54	124
	3.97	18.85	47.12	54.06	124.00
	0.23615	0.43034	0.31949	0.00008	*
All	8	38	95	109	250
	8.00	38.00	95.00	109.00	250.00
	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 20.015, DF = 6
Likelihood Ratio Chi-Square = 11.318, DF = 6

Tabulated statistics: x5, x27

Rows: x5 Columns: x27

	1	2	3	4	Missing	All
1	2	5	1	5	0	13
	0.57	1.78	4.75	5.90	*	13.00
	3.5393	5.8588	2.9615	0.1372	*	*
2	4	16	41	52	0	113
	4.99	15.43	41.30	51.28	*	113.00
	0.1971	0.0211	0.0021	0.0101	*	*
3	5	13	49	56	1	123
	5.43	16.80	44.95	55.82	*	123.00
	0.0346	0.8576	0.3646	0.0006	*	*
All	11	34	91	113	*	249
	11.00	34.00	91.00	113.00	*	249.00
	*	*	*	*	*	*

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 13.985, DF = 6
Likelihood Ratio Chi-Square = 12.141, DF = 6

Tabulated statistics: x5, x27

Rows: x5   Columns: x27

	1	2	3	4
1	2	5	1	5
	0.574	1.775	4.751	5.900
	3.5393	5.8588	2.9615	0.1372
2	4	16	41	52
	4.992	15.430	41.297	51.281
	0.1971	0.0211	0.0021	0.0101
3	5	13	49	56
	5.434	16.795	44.952	55.819
	0.0346	0.8576	0.3646	0.0006

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 13.985, DF = 6
Likelihood Ratio Chi-Square = 12.141, DF = 6

Tabulated statistics: x6, x12

Rows: x6   Columns: x12

	1	2	3	4
1	32	45	87	53
	31.248	45.136	90.272	50.344
	0.0181	0.0004	0.1186	0.1401
2	3	3	3	2
	1.584	2.288	4.576	2.552
	1.2658	0.2216	0.5428	0.1194
3	1	4	14	3
	3.168	4.576	9.152	5.104
	1.4837	0.0725	2.5681	0.8673

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 7.418, DF = 6, P-Value = 0.284
Likelihood Ratio Chi-Square = 7.557, DF = 6, P-Value = 0.272

Tabulated statistics: x6, x13

```
Rows: x6   Columns: x13

          1       2        3       4

1         7      77      118      15
      7.812  72.044  123.256  13.888
     0.0844  0.3409   0.2241  0.0890

2         1       1        9       0
      0.396   3.652    6.248   0.704
     0.9213  1.9258   1.2121  0.7040

3         1       5       15       1
      0.792   7.304   12.496   1.408
     0.0546  0.7268   0.5018  0.1182

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 6.903, DF = 6
Likelihood Ratio Chi-Square = 8.038, DF = 6
```

Tabulated statistics: x6, x15

```
Rows: x6   Columns: x15

          1       2       3       4

1        13     101      85      18
     13.888  97.216  87.668  18.228
     0.0568  0.1473  0.0812  0.0029

2         1       3       5       2
      0.704   4.928   4.444   0.924
     0.1245  0.7543  0.0696  1.2530

3         2       8      11       1
      1.408   9.856   8.888   1.848
     0.2489  0.3495  0.5019  0.3891

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 3.979, DF = 6
Likelihood Ratio Chi-Square = 3.808, DF = 6
```

Tabulated statistics: x6, x16

```
Rows: x6   Columns: x16

          1       2       3       4

1        13      96      90      18
     11.284  90.272  93.744  21.700
     0.2610  0.3635  0.1495  0.6309

2         0       2       6       3
      0.572   4.576   4.752   1.100
     0.5720  1.4501  0.3278  3.2818

3         0       6      12       4
      1.144   9.152   9.504   2.200
     1.1440  1.0856  0.6555  1.4727

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 11.394, DF = 6
Likelihood Ratio Chi-Square = 12.247, DF = 6
```

Tabulated statistics: x6, x17

```
Rows: x6   Columns: x17

           1        2        3        4

1         13       43      143       18
      12.152   42.532  143.220   19.096
     0.05918  0.00515  0.00034  0.06290

2          1        2        6        2
       0.616    2.156    7.260    0.968
     0.23938  0.01129  0.21868  1.10023

3          0        4       16        2
       1.232    4.312   14.520    1.936
     1.23200  0.02258  0.15085  0.00212

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 3.105, DF = 6
Likelihood Ratio Chi-Square = 4.046, DF = 6
```

Tabulated statistics: x6, x18

Rows: x6   Columns: x18

	1	2	3	4
1	9	72	125	11
	9.548	69.440	125.860	12.152
	0.03145	0.09438	0.00588	0.10921
2	1	2	7	1
	0.484	3.520	6.380	0.616
	0.55012	0.65636	0.06025	0.23938
3	1	6	13	2
	0.968	7.040	12.760	1.232
	0.00106	0.15364	0.00451	0.47875

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 2.385, DF = 6
Likelihood Ratio Chi-Square = 2.271, DF = 6

Tabulated statistics: x6, x19

Rows: x6   Columns: x19

	1	2	3	4
1	4	42	162	9
	5.208	41.664	161.448	8.680
	0.2802	0.0027	0.0019	0.0118
2	2	1	7	1
	0.264	2.112	8.184	0.440
	11.4155	0.5855	0.1713	0.7127
3	0	5	17	0
	0.528	4.224	16.368	0.880
	0.5280	0.1426	0.0244	0.8800

Cell Contents: Count
                    Expected count
                    Contribution to Chi-square

Pearson Chi-Square = 14.757, DF = 6
Likelihood Ratio Chi-Square = 9.354, DF = 6

Tabulated statistics: x6, x20

Rows: x6   Columns: x20

	1	2	3	4
1	46	71	87	13
	42.532	69.440	92.876	12.152
	0.2828	0.0350	0.3718	0.0592
2	1	3	6	1
	2.156	3.520	4.708	0.616
	0.6198	0.0768	0.3546	0.2394
3	2	6	14	0
	4.312	7.040	9.416	1.232
	1.2396	0.1536	2.2316	1.2320

```
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 6.896, DF = 6
Likelihood Ratio Chi-Square = 8.246, DF = 6
```

Tabulated statistics: x6, x21

Rows: x6   Columns: x21

	1	2	3	4
1	7	46	149	15
	7.812	46.872	144.088	18.228
	0.0844	0.0162	0.1675	0.5716
2	1	2	5	3
	0.396	2.376	7.304	0.924
	0.9213	0.0595	0.7268	4.6643
3	1	6	12	3
	0.792	4.752	14.608	1.848
	0.0546	0.3278	0.4656	0.7181

```
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 8.778, DF = 6
Likelihood Ratio Chi-Square = 6.770, DF = 6
```

Tabulated statistics: x6, x22

```
Rows: x6   Columns: x22

          1       2       3       4

1        24      98      57      38
     25.172  95.480  59.024  37.324
     0.0546  0.0665  0.0694  0.0122

2         4       2       4       1
      1.276   4.840   2.992   1.892
     5.8152  1.6664  0.3396  0.4205

3         1      10       7       4
      2.552   9.680   5.984   3.784
     0.9438  0.0106  0.1725  0.0123

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 9.584, DF = 6, P-Value = 0.143
Likelihood Ratio Chi-Square = 8.273, DF = 6, P-Value = 0.219
```

Tabulated statistics: x6, x23

```
Rows: x6   Columns: x23

          1       2        3       4

1        12      38      115      52
     13.020  35.588  111.972  56.420
     0.0799  0.1635   0.0819  0.3463

2         2       1        4       4
      0.660   1.804    5.676   2.860
     2.7206  0.3583   0.4949  0.4544

3         1       2       10       9
      1.320   3.608   11.352   5.720
     0.0776  0.7166   0.1610  1.8808

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 7.536, DF = 6
Likelihood Ratio Chi-Square = 6.525, DF = 6
```

Tabulated statistics: x6, x24

Rows: x6   Columns: x24

	1	2	3	4
1	10	25	84	98
	8.680	26.040	79.856	102.424
	0.2007	0.0415	0.2150	0.1911
2	0	2	3	6
	0.440	1.320	4.048	5.192
	0.4400	0.3503	0.2713	0.1257
3	0	3	5	14
	0.880	2.640	8.096	10.384
	0.8800	0.0491	1.1839	1.2592

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 5.208, DF = 6
Likelihood Ratio Chi-Square = 6.553, DF = 6

Tabulated statistics: x6, x25

Rows: x6   Columns: x25

	1	2	3	4
1	11	56	88	62
	11.284	52.080	88.536	65.100
	0.00715	0.29505	0.00324	0.14762
2	1	1	5	4
	0.572	2.640	4.488	3.300
	0.32025	1.01879	0.05841	0.14848
3	1	3	9	9
	1.144	5.280	8.976	6.600
	0.01813	0.98455	0.00006	0.87273

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 3.874, DF = 6
Likelihood Ratio Chi-Square = 4.213, DF = 6

Tabulated statistics: x6, x26

Rows: x6   Columns: x26

	1	2	3	4
1	6	33	84	94
	6.944	32.984	82.460	94.612
	0.12833	0.00001	0.02876	0.00396
2	1	1	4	5
	0.352	1.672	4.180	4.796
	1.19291	0.27009	0.00775	0.00868
3	1	4	7	10
	0.704	3.344	8.360	9.592
	0.12445	0.12869	0.22124	0.01735

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 2.132, DF = 6
Likelihood Ratio Chi-Square = 1.774, DF = 6

Tabulated statistics: x6, x27

Rows: x6   Columns: x27

	1	2	3	4
1	11	26	81	99
	9.586	29.631	79.305	98.478
	0.2085	0.4448	0.0362	0.0028
2	0	3	5	2
	0.442	1.365	3.655	4.538
	0.4418	1.9566	0.4953	1.4196
3	0	5	5	12
	0.972	3.004	8.040	9.984
	0.9719	1.3262	1.1496	0.4071

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 8.860, DF = 6
Likelihood Ratio Chi-Square = 10.041, DF = 6

Tabulated statistics: x7, x22

Rows: x7   Columns: x22

	1	2	3	4
1	22	97	59	38
	25.056	95.040	58.752	37.152
	0.3727	0.0404	0.0010	0.0194
2	4	5	5	4
	2.088	7.920	4.896	3.096
	1.7508	1.0766	0.0022	0.2640
3	3	8	4	1
	1.856	7.040	4.352	2.752
	0.7051	0.1309	0.0285	1.1154

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 5.507, DF = 6, P-Value = 0.481
Likelihood Ratio Chi-Square = 5.537, DF = 6, P-Value = 0.477

Tabulated statistics: x8, x22

Rows: x8   Columns: x22

	1	2	3	4
1	16	51	42	21
	15.08	57.20	35.36	22.36
	0.0561	0.6720	1.2469	0.0827
2	8	47	19	20
	10.90	41.36	25.57	16.17
	0.7734	0.7691	1.6872	0.9082
3	5	12	7	2
	3.02	11.44	7.07	4.47
	1.3051	0.0274	0.0007	1.3665

Cell Contents: Count
Expected count
Contribution to Chi-square

Pearson Chi-Square = 8.895, DF = 6, P-Value = 0.180
Likelihood Ratio Chi-Square = 9.140, DF = 6, P-Value = 0.166

Tabulated statistics: x9, x22

```
Rows: x9   Columns: x22

            1        2        3        4

1          27      105       67       41
        27.84   105.60    65.28    41.28
      0.02534  0.00341  0.04532  0.00190

2           2        5        1        2
         1.16     4.40     2.72     1.72
      0.60828  0.08182  1.08765  0.04558

Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square


Pearson Chi-Square = 1.899, DF = 3, P-Value = 0.594
Likelihood Ratio Chi-Square = 2.135, DF = 3, P-Value = 0.545
```

APPENDIX C

TRANSYT-7F DETAILED OUTPUT

Tuesday-VMS is off

> PERFORMANCE WITH INITIAL SETTINGS<

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform veh-h	Delay Random veh-h	Delay Total veh-h	Delay Average sec/veh	Stops Uniform (vph(%,	Stops Random (vph(%,	Stops Total (vph(%,
NB THRU	1320	3600	246*	530.64	367.45	1002.1	116.72	243.36	360.08	982.0	1320.0(100%)	1000.0(76%)	2320.0(176%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2167	1800	480*	871.13	1346.80	2237.4	303.43	1031.27	1334.70	2217.3	2167.0(100%)	1000.0(47%)	3167.0(147%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	106	1800	69	42.61	3.88	131.8	2.62	0.67	3.29	111.7	100.4(95%)	16.5(16%)	116.9(111%(
11753	: 1	MAX =	480*	4724.71	3167.33		982.30	2119.41	3101.71	950.1	11107.0(95%)	7151.0(61%)	******(155%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 166.9 ( 636) 98.8 ( 376)265.7 (1012) 84.0 ( 320)   0.0    N     ****** 35.0     3      F
      LEFT 138.0 (1052) 82.2 ( 626)220.2 (1678) 36.0 ( 274)   0.0    N     ****** 35.0     3      F
      RGHT   4.4 (  30)  0.3 (   2)  4.7 (  32) 53.0 ( 404)   0.0    N      13.06 35.0     3      E

   SB THRU 185.9 ( 709) 69.1 ( 263)255.0 ( 972) 74.0 ( 282)   0.0    N     676.71 80.0     3      F
      LEFT  63.5 ( 488) 18.0 ( 137) 81.5 ( 625) 36.0 ( 274)   0.0    N     200.20 80.0     3      F
      RGHT  84.7 ( 648) 29.5 ( 224)114.2 ( 872) 35.0 ( 267)   0.0    N     291.93 80.0     3      F

   EB THRU 264.8 (1010)115.5 ( 440)380.3 (1450) 77.0 ( 293)   0.0    N     ****** 40.0     3      F
      LEFT 390.4 (2972)215.0 (1638)605.4 (4610) 20.0 ( 152)   0.0    N     ****** 40.0     3      F
      RGHT  11.9 (  91)  0.7 (   5) 12.6 (  96) 51.0 ( 389)   0.0    N      39.40 40.0     3      F

   WB THRU  83.0 ( 316) 52.6 ( 200)135.6 ( 516) 92.0 ( 351)   0.0    N     583.52 20.0     3      F
      LEFT  37.5 ( 290) 24.2 ( 185) 61.8 ( 475) 44.0 ( 335)   0.0    N     258.94 20.0     3      F
      RGHT   5.2 (  38)  1.0 (   7)  6.1 (  45) 52.0 ( 396)   0.0    N      17.23 20.0     3      F

) 9497.31        0                                                   : 1     DI= 2496.1)     F
--------------------------------------------------------------------------------------------------------------------------------
--
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
----------------------------------------------------------------------------------------------------------------------------------
--

   NB THRU   2741  5400    51  1101.88  15.57   20.4   0.00    0.26    0.26    0.3     0.0(  0%)  16.7(  1%)  16.7(  1%(
      RGHT    852  1800    47   342.50   4.97   21.0   0.00    0.21    0.21    0.9     0.0(  0%)  14.5(  2%)  14.5(  2%(

   3593     : 2     MAX =  51  1444.39  20.53          0.00    0.47    0.47    0.5     0.0(  0%)  31.2(  1%)  31.2(  1%(
----------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
----------------------------------------------------------------------------------------------------------------------------------
--

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (   0)  0.4 (   3)  0.4 (   3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 117.97          0                                                     : 2     DI=    0.7      (
----------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
----------------------------------------------------------------------------------------------------------------------------------
   ---NB THRU   2741  5400    51  1101.88  15.57   20.4   0.00    0.26    0.26    0.3     0.0(  0%)  16.7(  1%)  16.7(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   3101     : 3     MAX =  51  1246.60  17.60          0.00    0.29    0.29    0.3     0.0(  0%)  20.7(  1%)  20.7(  1%(
----------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %             lit   sec
-------------------------------------------------------------------------------------------------------------------------------
--

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 101.48          0                                                           : 3     DI=    0.5      (
-------------------------------------------------------------------------------------------------------------------------------
--

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                 (vph(%,
-------------------------------------------------------------------------------------------------------------------------------
-

   NB THRU   3101  5400    57  1246.60  17.70   20.5   0.00    0.39    0.39    0.4     0.0(  0%)  21.8(  1%)  21.8(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3521     : 4     MAX =***** 1415.441067.70         47.66 1000.39 1048.04 1071.6   420.0( 12%)1021.8( 29%)1441.8( 41%(
-------------------------------------------------------------------------------------------------------------------------------
-

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %             lit   sec
-------------------------------------------------------------------------------------------------------------------------------
   --NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085)  43.0 ( 328)   0.0    N     ******  20.0     6

) 3039.37         0                                                           : 4     DI=  785.3      (
-------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3361  5400    62  1351.12  19.28   20.6   0.00    0.51    0.51    0.5     0.0(  0%)  26.6(  1%)  26.6(  1%(
      RGHT    160  1800     9    64.32   0.90   20.2   0.00    0.00    0.00    0.1     0.0(  0%)   1.6(  1%)   1.6(  1%(

   3521     : 5     MAX =  62  1415.44  20.17          0.00    0.52    0.52    0.5     0.0(  0%)  28.2(  1%)  28.2(  1%(
-------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %             lit   sec
-------------------------------------------------------------------------------------------------------------------------------
--

   NB THRU   0.0 (   0)  0.8 (   2)  0.8 (   2)156.0 ( 396)   0.0    N       5.21  20.0     6
      RGHT   0.0 (   0)  0.0 (   0)  0.0 (   0) 53.0 ( 404)   0.0    N       5.21  20.0     6

) 115.75          0                                                      : 5     DI=    0.7      (
-------------------------------------------------------------------------------------------------------------------------------
--

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
-------------------------------------------------------------------------------------------------------------------------------
   --NB THRU   3361  5400    62  1351.12  19.28   20.6   0.00    0.51    0.51    0.5     0.0(  0%)  26.6(  1%)  26.6(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   3561     : 6     MAX =***** 1431.521042.50         22.11 1000.51 1022.62 1033.8   200.0(  6%)1026.6( 29%)1226.6( 34%(
-------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
--
   NB THRU   0.0 (   0)  0.8 (   2)  0.8 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2959.96        0                                                          : 6     DI=  764.0      (
--------------------------------------------------------------------------------------------------------------------------------
--
 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
-
   NB THRU   3486  3600P  217* 1401.37 649.79  671.0 116.71  513.62  630.33  650.9  3486.0(100%)1000.0( 29%)4486.0(129%(

   SB THRU    930  3600   152*  373.86 132.87  514.3  65.31   62.37  127.67  494.2   930.0(100%) 566.2( 61%)1496.2(161%(
      LEFT    375  1800   122*  150.75  33.54  322.0  18.27   13.18   31.45  301.9   314.8( 84%) 148.3( 40%) 463.1(124%(
      RGHT    180  1800    59    72.36   5.90  118.0   4.49    0.40    4.90   97.9   103.9( 58%)   9.4(  6%) 113.3( 63%(

   EB THRU    520  3600P  124*  209.04  37.40  258.9  15.98   18.52   34.50  238.8   520.0(100%) 205.1( 40%) 725.1(140%(
      RGHT    240  1800   104*   96.48  14.05  210.7   7.93    4.78   12.71  190.6   205.9( 86%)  62.9( 27%) 268.8(112%(

   WB THRU    320  1800   139*  128.64  43.41  488.3  23.72   17.90   41.62  468.2   320.0(100%) 177.0( 56%) 497.0(156%(
      LEFT    700  1800   305*  281.40 281.67 1448.6  96.34  181.42  277.76 1428.5   700.0(100%) 820.5(118%)1520.5(218%(
      RGHT    120  1800    52    48.24   4.14  124.2   3.19    0.28    3.47  104.1   110.1( 92%)   7.3(  7%) 117.4( 98%(

(%51 )25.4  (%1  )0.4   (%50 )25.0    30.1   0.42    0.00    0.42   50.2   0.70   20.10    6     1800  50     713   7
(%50 )12.5  (%1  )0.2   (%49 )12.3    29.6   0.21    0.00    0.21   49.7   0.35   10.05    3     1800  25     714   7
(%77 )38.2  (%4  )1.9   (%73 )36.3    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50     715   7
(%92 )45.9  (%4  )1.9   (%88 )44.0    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50     716   7

   7046     : 7     MAX = 305* 2832.491206.98        355.12  812.53 1167.64  596.6  6808.3( 97%)3001.1( 43%)9809.4(139%(
--------------------------------------------------------------------------------------------------------------------------------
--
```

```
 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------    %              lit   sec
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 247.2 ( 941)236.2 ( 900)483.4 (1841)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0   (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0   (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 3782.63        0                                                     : 7     DI=  975.7)     F
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All MOEs are in units per hour  .
```

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	14511
Total Travel Time	veh-hr/hr	6543
Total Uniform Delay	veh-hr/hr	1407
Total Random Delay	veh-hr/hr	4934
Total Delay	veh-hr/hr	6341
Average Delay	sec/veh	632.4
Passenger Delay	pax-hr/hr	7610
Uniform Stops:	veh/hr	18535
%		51
Random Stops:	veh/hr	12281
%		34
Total Stops:	veh/hr	30816
%		85
Degree of Sat > 1	# of links	18
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.2
Fuel Consumption	lit/hr	19614
Operating Cost	$/hr	22997
Performance Index	DI	5023 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

Tuesday- VMS is on

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform	Delay Random veh-h	Delay Total	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	980	3600	183*	393.96	172.73	634.5	63.83	103.43	167.26	614.4	980.0(100%)	964.5(99%)	1944.5(199%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2074	1800	459*	833.75	1233.25	2140.7	287.98	933.69	1221.67	2120.6	2074.0(100%)	1000.0(49%)	3074.0(149%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	120	1800	78	48.24	4.72	141.7	2.98	1.07	4.05	121.6	114.5(95%)	23.2(20%)	137.7(115%(
11334	: 1	MAX =	459*	4556.27	2859.91		914.33	1882.30	2796.63	888.3	10688.0(94%)	7122.2(63%)	******(157%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total      Capacity   Full  Link      Cons. Green   Type   LOS
--------------          veh/link( m/lane)---------------     %               lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU  92.2 ( 351) 56.6 ( 215)148.8 ( 566) 88.0 ( 335)   0.0    N     541.12  35.0     3      F
      LEFT 138.0 (1052) 82.2 ( 626)220.2 (1678) 36.0 ( 274)   0.0    N     ******  35.0     3      F
      RGHT   4.4 (  30)  0.3 (   2)  4.7 (  32) 53.0 ( 404)   0.0    N      13.06  35.0     3      E

   SB THRU 185.9 ( 709) 69.1 ( 263)255.0 ( 972) 74.0 ( 282)   0.0    N     676.71  80.0     3      F
      LEFT  63.5 ( 488) 18.0 ( 137) 81.5 ( 625) 36.0 ( 274)   0.0    N     200.20  80.0     3      F
      RGHT  84.7 ( 648) 29.5 ( 224)114.2 ( 872) 35.0 ( 267)   0.0    N     291.93  80.0     3      F

   EB THRU 264.8 (1010)115.5 ( 440)380.3 (1450) 77.0 ( 293)   0.0    N     ******  40.0     3      F
      LEFT 371.9 (2835)203.4 (1550)575.3 (4385) 21.0 ( 160)   0.0    N     ******  40.0     3      F
      RGHT  11.9 (  91)  0.7 (   5) 12.6 (  96) 51.0 ( 389)   0.0    N      39.40  40.0     3      F

   WB THRU  83.0 ( 316) 52.6 ( 200)135.6 ( 516) 92.0 ( 351)   0.0    N     583.52  20.0     3      F
      LEFT  37.5 ( 290) 24.2 ( 185) 61.8 ( 475) 44.0 ( 335)   0.0    N     258.94  20.0     3      F
      RGHT   5.9 (  46)  1.4 (  10)  7.3 (  56) 52.0 ( 396)   0.0    N      20.46  20.0     3      F

) 8618.43         0                                                      : 1     DI= 2267.1)     F
--------------------------------------------------------------------------------------------------------------------------------
--

 Movement/    Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.            Flow  of Sat  Travel  Total    Avg  Uniform Random    Total Average    Uniform      Random       Total
              vph    vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                 (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU    2322  5400    43   933.44  13.13   20.4   0.00     0.16    0.16    0.3     0.0(  0%)  12.2(  1%)  12.2(  1%(
      RGHT     852  1800    47   342.50   4.97   21.0   0.00     0.21    0.21    0.9     0.0(  0%)  14.5(  2%)  14.5(  2%(

   3174     : 2     MAX =  47  1275.95  18.10           0.00     0.37    0.37    0.4     0.0(  0%)  26.7(  1%)  26.7(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.4 (   1)  0.4 (   1)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (   0)  0.4 (   3)  0.4 (   3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 104.09          0                                                      : 2     DI=    0.6      (
-------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                 (vph(%,
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2322  5400    43   933.44  13.13   20.4   0.00    0.16    0.16    0.3     0.0(  0%)  12.2(  1%)  12.2(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   2682     : 3     MAX =  43  1078.16  15.16          0.00    0.19    0.19    0.3     0.0(  0%)  16.3(  1%)  16.3(  1%(
-------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.4 (   1)  0.4 (   1)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 87.60           0                                                      : 3     DI=    0.3      (
-------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
            vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2682  5400    50  1078.16  15.22   20.4   0.00    0.24    0.24    0.3     0.0(  0%)  16.0(  1%)  16.0(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3102     : 4     MAX =***** 1247.001065.22         47.66 1000.24 1047.90 1216.1   420.0( 14%)1016.0( 33%)1436.0( 46%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085) 43.0 ( 328)   0.0    N     ******  20.0     6

) 3025.37         0                                                     : 4     DI=  785.1      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
            vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3102  5400    57  1247.00  17.71   20.5   0.00    0.39    0.39    0.4     0.0(  0%)  21.8(  1%)  21.8(  1%(
      RGHT    211  1800    12    84.82   1.19   20.2   0.00    0.01    0.01    0.1     0.0(  0%)   2.2(  2%)   2.2(  2%(

   3313     : 5     MAX =  57  1331.83  18.89          0.00    0.39    0.39    0.4     0.0(  0%)  24.0(  1%)  24.0(  1%(
-----------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N       6.87  20.0     6
      RGHT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N       6.87  20.0     6

) 108.66         0                                                   : 5     DI=    0.6      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                  (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3102  5400    57  1247.00  17.71   20.5   0.00    0.39    0.39    0.4     0.0(  0%)  21.8(  1%)  21.8(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   3302     : 6     MAX =***** 1327.401040.93         22.11 1000.39 1022.50 1114.8   200.0(  6%)1021.8( 31%)1221.8( 37%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2951.21        0                                                   : 6     DI=  763.9      (
-----------------------------------------------------------------------------------------------------------------------------
----
```

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform	Delay Random veh-h	Delay Total	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	3227	3600P	201*	1297.25	527.41	588.4	99.21	410.18	509.40	568.3	3159.7(98%)	1000.0(31%)	4159.7(129%(
SB THRU	930	3600	152*	373.86	132.87	514.3	65.31	62.37	127.67	494.2	930.0(100%)	566.2(61%)	1496.2(161%(
LEFT	375	1800	122*	150.75	33.54	322.0	18.27	13.18	31.45	301.9	314.8(84%)	148.3(40%)	463.1(124%(
RGHT	180	1800	59	72.36	5.90	118.0	4.49	0.40	4.90	97.9	103.9(58%)	9.4(6%)	113.3(63%(
EB THRU	520	3600P	124*	209.04	37.40	258.9	15.98	18.52	34.50	238.8	520.0(100%)	205.1(40%)	725.1(140%(
RGHT	240	1800	104*	96.48	14.05	210.7	7.93	4.78	12.71	190.6	205.9(86%)	62.9(27%)	268.8(112%(
WB THRU	320	1800	139*	128.64	43.41	488.3	23.72	17.90	41.62	468.2	320.0(100%)	177.0(56%)	497.0(156%(
LEFT	700	1800	305*	281.40	281.67	1448.6	96.34	181.42	277.76	1428.5	700.0(100%)	820.5(118%)	1520.5(218%(
RGHT	120	1800	52	48.24	4.14	124.2	3.19	0.28	3.47	104.1	110.1(92%)	7.3(7%)	117.4(98%(

(%51)25.4	(%1)0.4	(%50)25.0	30.1	0.42	0.00	0.42	50.2	0.70	20.10	6	1800	50	713	7
(%50)12.5	(%1)0.2	(%49)12.3	29.6	0.21	0.00	0.21	49.7	0.35	10.05	3	1800	25	714	7
(%77)38.2	(%4)1.9	(%73)36.3	94.2	1.31	0.03	1.28	114.3	1.59	20.10	22	1800	50	715	7
(%92)45.9	(%4)1.9	(%88)44.0	94.2	1.31	0.03	1.28	114.3	1.59	20.10	22	1800	50	716	7

6787	: 7	MAX = 305*	2728.37	1084.61	337.62	709.09	1046.71	555.2	6482.0(96%)	3001.1(44%)	9483.1(140%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 221.2 ( 842)203.8 ( 777)425.1 (1619)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0   (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0   (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 3423.78        0                                                      : 7     DI=  883.2)     F
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----
```

All MOEs are in units per hour .

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	13545
Total Travel Time	veh-hr/hr	6103
Total Uniform Delay	veh-hr/hr	1322
Total Random Delay	veh-hr/hr	4593
Total Delay	veh-hr/hr	5915
Average Delay	sec/veh	631.9
Passenger Delay	pax-hr/hr	7098
Uniform Stops:	veh/hr	17790
%		53
Random Stops:	veh/hr	12228
%		36
Total Stops:	veh/hr	30018
%		89
Degree of Sat > 1	# of links	18
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.2
Fuel Consumption	lit/hr	18319
Operating Cost	$/hr	21519
Performance Index	DI	4701 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

Wednesday- VMS is off

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform veh-h	Delay Random veh-h	Delay Total veh-h	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	1061	3600	198*	426.52	214.20	726.8	76.43	131.85	208.28	706.7	1061.0(100%)	1000.0(95%)	2061.0(195%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2719	1800	602*	1093.04	2119.24	2805.9	395.12	1708.94	2104.06	2785.8	2719.0(100%)	1000.0(37%)	3719.0(137%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	139	1800	91	55.88	6.25	162.0	3.48	2.00	5.48	141.9	133.8(96%)	37.4(27%)	171.2(124%(
12079	: 1	MAX =	602*	4855.76	3788.90		1034.57	2686.89	3721.46	1109.1	11433.4(95%)	7171.9(59%)	******(154%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 108.9 ( 415) 66.6 ( 254)175.5 ( 669) 87.0 ( 331)   0.0    N     661.23  35.0     3       F
      LEFT 138.0 (1052) 82.2 ( 626)220.2 (1678) 36.0 ( 274)   0.0    N     ******  35.0     3       F
      RGHT   4.4 (  30)  0.3 (   2)  4.7 (  32) 53.0 ( 404)   0.0    N      13.06  35.0     3       E

   SB THRU 185.9 ( 709) 69.1 ( 263)255.0 ( 972) 74.0 ( 282)   0.0    N     676.71  80.0     3       F
      LEFT  63.5 ( 488) 18.0 ( 137) 81.5 ( 625) 36.0 ( 274)   0.0    N     200.20  80.0     3       F
      RGHT  84.7 ( 648) 29.5 ( 224)114.2 ( 872) 35.0 ( 267)   0.0    N     291.93  80.0     3       F

   EB THRU 264.8 (1010)115.5 ( 440)380.3 (1450) 77.0 ( 293)   0.0    N     ******  40.0     3       F
      LEFT 500.0 (3810)284.0 (2164)784.0 (5974) 13.0 (  99)   0.0    N     ******  40.0     3       F
      RGHT  11.9 (  91)  0.7 (   5) 12.6 (  96) 51.0 ( 389)   0.0    N      39.40  40.0     3       F

   WB THRU  83.0 ( 316) 52.6 ( 200)135.6 ( 516) 92.0 ( 351)   0.0    N     583.52  20.0     3       F
      LEFT  37.5 ( 290) 24.2 ( 185) 61.8 ( 475) 44.0 ( 335)   0.0    N     258.94  20.0     3       F
      RGHT   6.9 (  53)  2.2 (  17)  9.1 (  70) 51.0 ( 389)   0.0    N      25.93  20.0     3       F

) 11241.23        0                                                  : 1     DI= 2954.2)     F
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/    Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.            Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform      Random       Total
              vph   vphg    %     veh-km  veh-h sec/v        veh-h            sec/veh                 (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3067  5400    57  1232.93  17.50   20.5   0.00    0.37    0.37    0.4     0.0(  0%)  21.2(  1%)  21.2(  1%(
      RGHT    852  1800    47   342.50   4.97   21.0   0.00    0.21    0.21    0.9     0.0(  0%)  14.5(  2%)  14.5(  2%(

   3919     : 2     MAX =  57  1575.44  22.47          0.00    0.58    0.58    0.5     0.0(  0%)  35.8(  1%)  35.8(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (   0)  0.4 (   3)  0.4 (   3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 128.86         0                                                     : 2     DI=    0.9      (
----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3067  5400    57  1232.93  17.50   20.5   0.00    0.37    0.37    0.4     0.0(  0%)  21.2(  1%)  21.2(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   3427     : 3     MAX =  57  1377.65  19.53          0.00    0.40    0.40    0.4     0.0(  0%)  25.3(  1%)  25.3(  1%(
----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 112.37         0                                                     : 3     DI=    0.6      (
----------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                  (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3427  5400    63  1377.65  19.68   20.7   0.00    0.55    0.55    0.6     0.0(  0%)  28.0(  1%)  28.0(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3847     : 4     MAX =***** 1546.491069.68         47.66 1000.55 1048.20  980.9   420.0( 11%)1028.0( 27%)1448.0( 38%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.9 (   2)  0.9 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085)  43.0 ( 328)   0.0    N     ******  20.0     6

) 3050.41         0                                                      : 4     DI=  785.5      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                  (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3458  5400    64  1390.12  19.88   20.7   0.00    0.57    0.57    0.6     0.0(  0%)  28.7(  1%)  28.7(  1%(
      RGHT    389  1800    22   156.38   2.20   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.5(  2%)   4.5(  2%(

   3847     : 5     MAX =   64  1546.49  22.08          0.00    0.60    0.60    0.6     0.0(  0%)  33.2(  1%)  33.2(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.9 (   2)  0.9 (   2)156.0 ( 396)   0.0    N      12.71  20.0     6
      RGHT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      12.71  20.0     6

) 126.56         0                                                     : 5     DI=    0.8      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h           sec/veh                (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3458  5400    64  1390.12  19.88   20.7   0.00    0.57    0.57    0.6     0.0(  0%)  28.7(  1%)  28.7(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   3658     : 6     MAX =***** 1470.521043.10         22.11 1000.57 1022.68 1006.5   200.0(  5%)1028.7( 28%)1228.7( 34%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.9 (   2)  0.9 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2963.27        0                                                     : 6     DI=  764.1      (
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform      Random       Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                  (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3583  3600P  224* 1440.37 698.85  702.2 122.95  555.90  678.85  682.1  3583.0(100%)1000.0( 28%)4583.0(128%(

   SB THRU    930  3600   152*  373.86 132.87  514.3  65.31   62.37  127.67  494.2   930.0(100%) 566.2( 61%)1496.2(161%(
      LEFT    375  1800   122*  150.75  33.54  322.0  18.27   13.18   31.45  301.9   314.8( 84%) 148.3( 40%) 463.1(124%(
      RGHT    180  1800    59    72.36   5.90  118.0   4.49    0.40    4.90   97.9   103.9( 58%)   9.4(  6%) 113.3( 63%(

   EB THRU    520  3600P  124*  209.04  37.40  258.9  15.98   18.52   34.50  238.8   520.0(100%) 205.1( 40%) 725.1(140%(
      RGHT    240  1800   104*   96.48  14.05  210.7   7.93    4.78   12.71  190.6   205.9( 86%)  62.9( 27%) 268.8(112%(

   WB THRU    320  1800   139*  128.64  43.41  488.3  23.72   17.90   41.62  468.2   320.0(100%) 177.0( 56%) 497.0(156%(
      LEFT    700  1800   305*  281.40 281.67 1448.6  96.34  181.42  277.76 1428.5   700.0(100%) 820.5(118%)1520.5(218%(
      RGHT    120  1800    52    48.24   4.14  124.2   3.19    0.28    3.47  104.1   110.1( 92%)   7.3(  7%) 117.4( 98%(

(%51 )25.4  (%1  )0.4   (%50 )25.0    30.1   0.42    0.00    0.42   50.2   0.70   20.10    6     1800  50      713   7
(%50 )12.5  (%1  )0.2   (%49 )12.3    29.6   0.21    0.00    0.21   49.7   0.35   10.05    3     1800  25      714   7
(%77 )38.2  (%4  )1.9   (%73 )36.3    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      715   7
(%92 )45.9  (%4  )1.9   (%88 )44.0    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      716   7

   7143     : 7     MAX = 305* 2871.491256.05         361.36  854.81 1216.17  612.9  6905.3( 97%)3001.1( 42%)9906.4(139%(
-----------------------------------------------------------------------------------------------------------------------------
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```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 256.5 ( 979)248.5 ( 947)505.0 (1926)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0    (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0    (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0    (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0    (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 3924.81         0                                                  : 7     DI= 1012.5)     F
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All MOEs are in units per hour .

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	15244
Total Travel Time	veh-hr/hr	7222
Total Uniform Delay	veh-hr/hr	1466
Total Random Delay	veh-hr/hr	5544
Total Delay	veh-hr/hr	7010
Average Delay	sec/veh	665.5
Passenger Delay	pax-hr/hr	8412
Uniform Stops:	veh/hr	18959
%		50
Random Stops:	veh/hr	12324
%		32
Total Stops:	veh/hr	31283
%		82
Degree of Sat > 1	# of links	18
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.1
Fuel Consumption	lit/hr	21548
Operating Cost	$/hr	25075
Performance Index	DI	5519 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

Wednesday –VMS is on

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform	Delay Random veh-h	Delay Total	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	1090	3600	203*	438.18	229.80	759.0	80.94	142.78	223.71	738.9	1090.0(100%)	1000.0(92%)	2090.0(192%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2669	1800	591*	1072.94	2042.33	2754.7	386.82	1640.61	2027.43	2734.6	2669.0(100%)	1000.0(38%)	3669.0(138%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	210	1800	137*	84.42	21.29	364.9	8.27	11.85	20.12	344.8	210.0(100%)	147.0(71%)	357.0(171%(
12129	: 1	MAX =	591*	4875.86	3742.62		1035.56	2639.34	3674.90	1090.7	11488.6(95%)	7281.5(60%)	******(155%(

Movement/ Node No.	Uniform	-------- Max Back of Queue -------- Random	Total	Queuing Capacity	Time Full %	Critical Link	Fuel Cons. lit	Eff. Green sec	Arr. Type	LOS
		veh/link(m/lane)								
NB THRU	115.0 (438)	70.2 (267)	185.2 (705)	87.0 (331)	0.0	N	706.31	35.0	3	F
LEFT	138.0 (1052)	82.2 (626)	220.2 (1678)	36.0 (274)	0.0	N	******	35.0	3	F
RGHT	4.4 (30)	0.3 (2)	4.7 (32)	53.0 (404)	0.0	N	13.06	35.0	3	E
SB THRU	185.9 (709)	69.1 (263)	255.0 (972)	74.0 (282)	0.0	N	676.71	80.0	3	F
LEFT	63.5 (488)	18.0 (137)	81.5 (625)	36.0 (274)	0.0	N	200.20	80.0	3	F
RGHT	84.7 (648)	29.5 (224)	114.2 (872)	35.0 (267)	0.0	N	291.93	80.0	3	F
EB THRU	264.8 (1010)	115.5 (440)	380.3 (1450)	77.0 (293)	0.0	N	******	40.0	3	F
LEFT	490.1 (3734)	277.7 (2116)	767.8 (5850)	14.0 (107)	0.0	N	******	40.0	3	F
RGHT	11.9 (91)	0.7 (5)	12.6 (96)	51.0 (389)	0.0	N	39.40	40.0	3	F
WB THRU	83.0 (316)	52.6 (200)	135.6 (516)	92.0 (351)	0.0	N	583.52	20.0	3	F
LEFT	37.5 (290)	24.2 (185)	61.8 (475)	44.0 (335)	0.0	N	258.94	20.0	3	F
RGHT	13.1 (99)	8.6 (66)	21.7 (165)	47.0 (358)	0.0	N	72.36	20.0	3	F
) 11116.34	0						: 1	DI= 2922.2)		F

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Avg sec/v	------------ Delay ----------- Uniform	Random veh-h	Total	Average sec/veh	------------- Stops------------- Uniform	Random (vph(%,	Total
NB THRU	3117	5400	58	1253.03	17.80	20.6	0.00	0.39	0.39	0.5	0.0(0%)	22.1(1%)	22.1(1%(
RGHT	852	1800	47	342.50	4.97	21.0	0.00	0.21	0.21	0.9	0.0(0%)	14.5(2%)	14.5(2%(
3969	: 2	MAX =	58	1595.54	22.77		0.00	0.61	0.61	0.5	0.0(0%)	36.6(1%)	36.6(1%(

```
 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (   0)  0.4 (   3)  0.4 (   3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 130.54          0                                                           : 2     DI=    0.9      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3117  5400    58  1253.03  17.80   20.6   0.00    0.39    0.39    0.5     0.0(  0%)  22.1(  1%)  22.1(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   3477     : 3     MAX =  58  1397.75  19.83          0.00    0.42    0.42    0.4     0.0(  0%)  26.1(  1%)  26.1(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 114.05          0                                                           : 3     DI=    0.6      (
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3477  5400    64  1397.75  19.99   20.7   0.00    0.58    0.58    0.6     0.0(  0%)  29.2(  1%)  29.2(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3897     : 4     MAX =***** 1566.591069.99         47.66 1000.58 1048.24  968.3   420.0( 11%)1029.2( 26%)1449.2( 37%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------             veh/link( m/lane)---------------     %             lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.9 (   2)  0.9 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085)  43.0 ( 328)   0.0    N     ******  20.0     6

) 3052.12        0                                                          : 4     DI=  785.5      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3314  5400    61  1332.23  18.99   20.6   0.00    0.49    0.49    0.5     0.0(  0%)  25.7(  1%)  25.7(  1%(
      RGHT    583  1800    32   234.37   3.33   20.6   0.00    0.08    0.08    0.5     0.0(  0%)   7.7(  2%)   7.7(  2%(

   3897     : 5     MAX =  61  1566.59  22.32          0.00    0.56    0.56    0.5     0.0(  0%)  33.4(  1%)  33.4(  1%(
-----------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.8 (   2)  0.8 (   2)156.0 ( 396)   0.0    N      19.14  20.0     6
      RGHT   0.0 (   0)  0.2 (   2)  0.2 (   2) 53.0 ( 404)   0.0    N      19.14  20.0     6

) 128.09         0                                                        : 5     DI=    0.8      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                 (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3314  5400    61  1332.23  18.99   20.6   0.00    0.49    0.49    0.5     0.0(  0%)  25.7(  1%)  25.7(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   3514     : 6     MAX =***** 1412.631042.22         22.11 1000.49 1022.60 1047.6   200.0(  6%)1025.7( 29%)1225.7( 35%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.8 (   2)  0.8 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2958.37        0                                                        : 6     DI=  764.0      (
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform      Random       Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                 (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU    3439  3600P  214* 1382.48 626.73  656.1 113.70  493.83  607.53  636.0  3439.0(100%)1000.0( 30%)4439.0(130%(

   SB THRU     930  3600   152*  373.86 132.87  514.3  65.31   62.37  127.67  494.2   930.0(100%) 566.2( 61%)1496.2(161%(
      LEFT     375  1800   122*  150.75  33.54  322.0  18.27   13.18   31.45  301.9   314.8( 84%) 148.3( 40%) 463.1(124%(
      RGHT     180  1800    59    72.36   5.90  118.0   4.49    0.40    4.90   97.9   103.9( 58%)   9.4(  6%) 113.3( 63%(

   EB THRU     520  3600P  124*  209.04  37.40  258.9  15.98   18.52   34.50  238.8   520.0(100%) 205.1( 40%) 725.1(140%(
      RGHT     240  1800   104*   96.48  14.05  210.7   7.93    4.78   12.71  190.6   205.9( 86%)  62.9( 27%) 268.8(112%(

   WB THRU     320  1800   139*  128.64  43.41  488.3  23.72   17.90   41.62  468.2   320.0(100%) 177.0( 56%) 497.0(156%(
      LEFT     700  1800   305*  281.40 281.67 1448.6  96.34  181.42  277.76 1428.5   700.0(100%) 820.5(118%)1520.5(218%(
      RGHT     120  1800    52    48.24   4.14  124.2   3.19    0.28    3.47  104.1   110.1( 92%)   7.3(  7%) 117.4( 98%(

(%51 )25.4  (%1  )0.4   (%50 )25.0    30.1   0.42    0.00    0.42   50.2   0.70   20.10    6     1800  50      713   7
(%50 )12.5  (%1  )0.2   (%49 )12.3    29.6   0.21    0.00    0.21   49.7   0.35   10.05    3     1800  25      714   7
(%77 )38.2  (%4  )1.9   (%73 )36.3    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      715   7
(%92 )45.9  (%4  )1.9   (%88 )44.0    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      716   7

   6999     : 7     MAX = 305* 2813.601183.92         352.11  792.74 1144.84  588.9  6761.3( 97%)3001.1( 43%)9762.4(139%(
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 242.6 ( 926)230.3 ( 877)472.9 (1803)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0   (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0   (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 3715.70        0                                                          : 7     DI=  958.5)     F
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All MOEs are in units per hour .

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	15229
Total Travel Time	veh-hr/hr	7104
Total Uniform Delay	veh-hr/hr	1457
Total Random Delay	veh-hr/hr	5435
Total Delay	veh-hr/hr	6892
Average Delay	sec/veh	655.0
Passenger Delay	pax-hr/hr	8271
Uniform Stops:	veh/hr	18870
%		50
Random Stops:	veh/hr	12434
%		33
Total Stops:	veh/hr	31303
%		83
Degree of Sat > 1	# of links	19
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.1
Fuel Consumption	lit/hr	21215
Operating Cost	$/hr	24727
Performance Index	DI	5433 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

Thursday- VMS is off

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform	Delay Random veh-h	Delay Total	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	1115	3600	208*	448.23	243.56	786.4	84.83	152.51	237.34	766.3	1115.0(100%)	1000.0(90%)	2115.0(190%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2250	1800	498*	904.50	1452.18	2323.5	317.22	1122.40	1439.62	2303.4	2250.0(100%)	1000.0(45%)	3250.0(145%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	185	1800	121*	74.37	12.94	251.8	4.73	7.18	11.91	231.7	182.2(98%)	101.1(55%)	283.3(154%(
11710	: 1	MAX =	498*	4707.42	3157.88		966.31	2126.19	3092.50	950.7	11066.7(95%)	7235.6(62%)	******(156%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %               lit   sec
------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 120.5 ( 457) 73.3 ( 279)193.8 ( 736) 86.0 ( 328)   0.0     N     746.06  35.0     3      F
      LEFT 138.0 (1052) 82.2 ( 626)220.2 (1678) 36.0 ( 274)   0.0     N     ******  35.0     3      F
      RGHT   4.4 (  30)  0.3 (   2)  4.7 (  32) 53.0 ( 404)   0.0     N      13.06  35.0     3      E

   SB THRU 185.9 ( 709) 69.1 ( 263)255.0 ( 972) 74.0 ( 282)   0.0     N     676.71  80.0     3      F
      LEFT  63.5 ( 488) 18.0 ( 137) 81.5 ( 625) 36.0 ( 274)   0.0     N     200.20  80.0     3      F
      RGHT  84.7 ( 648) 29.5 ( 224)114.2 ( 872) 35.0 ( 267)   0.0     N     291.93  80.0     3      F

   EB THRU 264.8 (1010)115.5 ( 440)380.3 (1450) 77.0 ( 293)   0.0     N     ******  40.0     3      F
      LEFT 406.9 (3101)225.4 (1717)632.3 (4818) 19.0 ( 145)   0.0     N     ******  40.0     3      F
      RGHT  11.9 (  91)  0.7 (   5) 12.6 (  96) 51.0 ( 389)   0.0     N      39.40  40.0     3      F

   WB THRU  83.0 ( 316) 52.6 ( 200)135.6 ( 516) 92.0 ( 351)   0.0     N     583.52  20.0     3      F
      LEFT  37.5 ( 290) 24.2 ( 185) 61.8 ( 475) 44.0 ( 335)   0.0     N     258.94  20.0     3      F
      RGHT   9.4 (  69)  5.9 (  45) 15.3 ( 114) 48.0 ( 366)   0.0     N      47.50  20.0     3      F

) 9468.52         0                                                      : 1     DI= 2489.9)     F
------------------------------------------------------------------------------------------------------------------------------
----

 Movement/    Flow   Sat  Degree  Total    Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.            Flow  of Sat  Travel  Total    Avg  Uniform Random    Total Average    Uniform      Random       Total
              vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                   (vph(%,
------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2698  5400    50  1084.60  15.31   20.4   0.00    0.25    0.25    0.3     0.0(  0%)  16.2(  1%)  16.2(  1%(
      RGHT    852  1800    47   342.50   4.97   21.0   0.00    0.21    0.21    0.9     0.0(  0%)  14.5(  2%)  14.5(  2%(

   3550     : 2     MAX =  50  1427.10  20.28          0.00    0.46    0.46    0.5     0.0(  0%)  30.7(  1%)  30.7(  1%(
------------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------    %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (   0)  0.4 (   3)  0.4 (   3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 116.54          0                                                      : 2     DI=    0.7      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3067  5400    57  1232.93  17.50   20.5   0.00    0.37    0.37    0.4     0.0(  0%)  21.2(  1%)  21.2(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   3427     : 3     MAX =  57  1377.65  19.53          0.00    0.40    0.40    0.4     0.0(  0%)  25.3(  1%)  25.3(  1%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity  Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------    %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (   0)  0.1 (   1)  0.1 (   1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 112.37          0                                                      : 3     DI=    0.6      (
-----------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v        veh-h            sec/veh                 (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3058  5400    57  1229.32  17.44   20.5   0.00    0.37    0.37    0.4     0.0(  0%)  21.1(  1%)  21.1(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3478     : 4     MAX =***** 1398.161067.44         47.66 1000.37 1048.02 1084.8   420.0( 12%)1021.1( 29%)1441.1( 41%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.7 (   2)  0.7 (   2)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085)  43.0 ( 328)   0.0    N     ******  20.0     6

) 3037.93        0                                                          : 4     DI=  785.3      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v        veh-h            sec/veh                 (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2836  5400    53  1140.07  16.12   20.5   0.00    0.29    0.29    0.4     0.0(  0%)  17.9(  1%)  17.9(  1%(
      RGHT    642  1800    36   258.08   3.68   20.7   0.00    0.10    0.10    0.6     0.0(  0%)   9.0(  2%)   9.0(  2%(

   3478     : 5     MAX =  53  1398.16  19.81          0.00    0.39    0.39    0.4     0.0(  0%)  26.9(  1%)  26.9(  1%(
-----------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.6 (   1)  0.6 (   1)157.0 ( 399)   0.0    N      21.12  20.0     6
      RGHT   0.0 (   0)  0.3 (   2)  0.3 (   2) 52.0 ( 396)   0.0    N      21.12  20.0     6

) 114.00          0                                                        : 5     DI=    0.6      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                 (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2836  5400    53  1140.07  16.12   20.5   0.00    0.29    0.29    0.4     0.0(  0%)  17.9(  1%)  17.9(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   3036     : 6     MAX =***** 1220.471039.35         22.11 1000.29 1022.40 1212.3   200.0(  7%)1017.9( 34%)1217.9( 40%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.6 (   1)  0.6 (   1)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2942.30         0                                                        : 6     DI=  763.8      (
--------------------------------------------------------------------------------------------------------------------------------
----
```

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform	Delay Random veh-h	Delay Total	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	2961	3600P	185*	1190.32	412.74	501.8	80.83	315.38	396.21	481.7	2675.6(90%)	1000.0(34%)	3675.6(125%(
SB THRU	930	3600	152*	373.86	132.87	514.3	65.31	62.37	127.67	494.2	930.0(100%)	566.2(61%)	1496.2(161%(
LEFT	375	1800	122*	150.75	33.54	322.0	18.27	13.18	31.45	301.9	314.8(84%)	148.3(40%)	463.1(124%(
RGHT	180	1800	59	72.36	5.90	118.0	4.49	0.40	4.90	97.9	103.9(58%)	9.4(6%)	113.3(63%(
EB THRU	520	3600P	124*	209.04	37.40	258.9	15.98	18.52	34.50	238.8	520.0(100%)	205.1(40%)	725.1(140%(
RGHT	240	1800	104*	96.48	14.05	210.7	7.93	4.78	12.71	190.6	205.9(86%)	62.9(27%)	268.8(112%(
WB THRU	320	1800	139*	128.64	43.41	488.3	23.72	17.90	41.62	468.2	320.0(100%)	177.0(56%)	497.0(156%(
LEFT	700	1800	305*	281.40	281.67	1448.6	96.34	181.42	277.76	1428.5	700.0(100%)	820.5(118%)	1520.5(218%(
RGHT	120	1800	52	48.24	4.14	124.2	3.19	0.28	3.47	104.1	110.1(92%)	7.3(7%)	117.4(98%(

(%51)25.4	(%1)0.4	(%50)25.0	30.1	0.42	0.00	0.42	50.2	0.70	20.10	6	1800	50	713	7
(%50)12.5	(%1)0.2	(%49)12.3	29.6	0.21	0.00	0.21	49.7	0.35	10.05	3	1800	25	714	7
(%77)38.2	(%4)1.9	(%73)36.3	94.2	1.31	0.03	1.28	114.3	1.59	20.10	22	1800	50	715	7
(%92)45.9	(%4)1.9	(%88)44.0	94.2	1.31	0.03	1.28	114.3	1.59	20.10	22	1800	50	716	7

6521	: 7	MAX = 305*	2621.44	969.93		319.24	614.28	933.52	515.4	5997.9(92%)	3001.1(46%)	8999.0(138%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total      Capacity   Full  Link      Cons. Green   Type   LOS
--------------          veh/link( m/lane)---------------     %              lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 194.2 ( 739)170.7 ( 650)364.9 (1389)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0   (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0   (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 3078.82        0                                                      : 7     DI=  794.3)     F
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```

All MOEs are in units per hour .

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	14150
Total Travel Time	veh-hr/hr	6294
Total Uniform Delay	veh-hr/hr	1355
Total Random Delay	veh-hr/hr	4742
Total Delay	veh-hr/hr	6098
Average Delay	sec/veh	623.6
Passenger Delay	pax-hr/hr	7317
Uniform Stops:	veh/hr	17685
%		50
Random Stops:	veh/hr	12358
%		35
Total Stops:	veh/hr	30043
%		85
Degree of Sat > 1	# of links	19
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.2
Fuel Consumption	lit/hr	18870
Operating Cost	$/hr	22130
Performance Index	DI	4835 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

Thursday – VMS is on

Movement/ Node No.	Flow vph	Sat Flow vphg	Degree of Sat %	Total Travel veh-km	Travel Time Total veh-h	Travel Time Avg sec/v	Delay Uniform veh-h	Delay Random veh-h	Delay Total veh-h	Delay Average sec/veh	Stops Uniform	Stops Random (vph(%,	Stops Total
NB THRU	1098	3600	205*	441.40	234.17	767.8	82.18	145.86	228.04	747.7	1098.0(100%)	1000.0(92%)	2098.0(192%(
LEFT	920	1800	343*	369.84	386.14	1511.0	98.80	282.20	381.01	1490.9	920.0(100%)	1000.0(109%)	1920.0(209%(
RGHT	100	1800	37	40.20	2.62	94.5	1.96	0.11	2.07	74.4	87.7(88%)	5.0(6%)	92.7(93%(
SB THRU	2100	3600	134*	844.20	201.62	345.6	97.03	92.86	189.90	325.5	1764.0(84%)	1000.0(48%)	2764.0(132%(
LEFT	900	1800	115*	361.80	54.42	217.7	28.68	20.71	49.40	197.6	731.5(81%)	306.4(35%)	1037.9(116%(
RGHT	1000	1800	128*	402.00	85.22	306.8	41.91	37.73	79.63	286.7	831.5(83%)	502.4(51%)	1333.9(134%(
EB THRU	1820	3600	201*	731.64	432.07	854.7	189.26	232.65	421.91	834.6	1820.0(100%)	1000.0(55%)	2820.0(155%(
LEFT	2440	1800	540*	980.88	1707.75	2519.6	348.78	1345.35	1694.13	2499.5	2440.0(100%)	1000.0(41%)	3440.0(141%(
RGHT	260	1800	58	104.52	7.50	103.9	5.67	0.38	6.05	83.8	304.8(117%)	11.2(5%)	316.1(122%(
WB THRU	720	3600	235*	289.44	193.98	969.9	66.37	123.60	189.96	949.8	720.0(100%)	896.3(125%)	1616.3(225%(
LEFT	340	1800	222*	136.68	85.61	906.5	29.86	53.85	83.71	886.4	340.0(100%)	413.2(122%)	753.2(222%(
RGHT	202	1800	132*	81.20	18.29	325.9	6.94	10.22	17.16	305.8	202.0(100%)	131.9(66%)	333.9(166%(
11900	: 1		MAX = 540*	4783.80	3409.41		997.43	2345.54	3342.97	1011.3	11259.6(95%)	7266.4(61%)	******(156%(

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random        Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 116.7 ( 446) 71.2 ( 271)187.9 ( 717) 86.0 ( 328)   0.0    N     718.94  35.0     3      F
      LEFT 138.0 (1052) 82.2 ( 626)220.2 (1678) 36.0 ( 274)   0.0    N     ******  35.0     3      F
      RGHT   4.4 (  30)  0.3 (   2)  4.7 (  32) 53.0 ( 404)   0.0    N      13.06  35.0     3      E

   SB THRU 185.9 ( 709) 69.1 ( 263)255.0 ( 972) 74.0 ( 282)   0.0    N     676.71  80.0     3      F
      LEFT  63.5 ( 488) 18.0 ( 137) 81.5 ( 625) 36.0 ( 274)   0.0    N     200.20  80.0     3      F
      RGHT  84.7 ( 648) 29.5 ( 224)114.2 ( 872) 35.0 ( 267)   0.0    N     291.93  80.0     3      F

   EB THRU 264.8 (1010)115.5 ( 440)380.3 (1450) 77.0 ( 293)   0.0    N     ******  40.0     3      F
      LEFT 444.6 (3391)249.1 (1898)693.7 (5289) 17.0 ( 130)   0.0    N     ******  40.0     3      F
      RGHT  11.9 (  91)  0.7 (   5) 12.6 (  96) 51.0 ( 389)   0.0    N      39.40  40.0     3      F

   WB THRU  83.0 ( 316) 52.6 ( 200)135.6 ( 516) 92.0 ( 351)   0.0    N     583.52  20.0     3      F
      LEFT  37.5 ( 290) 24.2 ( 185) 61.8 ( 475) 44.0 ( 335)   0.0    N     258.94  20.0     3      F
      RGHT  11.7 (  91)  7.7 (  59) 19.4 ( 150) 47.0 ( 358)   0.0    N      63.53  20.0     3      F

) 10178.04       0                                                      : 1     DI= 2676.1)     F
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/    Flow   Sat  Degree  Total    Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.            Flow  of Sat  Travel   Total    Avg  Uniform Random    Total Average    Uniform      Random       Total
              vph   vphg    %     veh-km   veh-h sec/v         veh-h          sec/veh                  (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2888  5400    53  1160.98  16.43   20.5   0.00    0.31    0.31    0.4     0.0(  0%)  18.6(  1%)  18.6(  1%(
      RGHT    852  1800    47   342.50   4.97   21.0   0.00    0.21    0.21    0.9     0.0(  0%)  14.5(  2%)  14.5(  2%(

   3740     : 2     MAX =  53  1503.48  21.40          0.00    0.52    0.52    0.5     0.0(  0%)  33.1(  1%)  33.1(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (    0)  0.6 (    1)  0.6 (    1)157.0 ( 399)   0.0    N      28.25  20.0     6
      RGHT   0.0 (    0)  0.4 (    3)  0.4 (    3) 52.0 ( 396)   0.0    N      28.25  20.0     6

) 122.87          0                                                     : 2     DI=    0.8      (
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h           sec/veh                  (vph(%,
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2888  5400    53  1160.98  16.43   20.5   0.00    0.31    0.31    0.4     0.0(  0%)  18.6(  1%)  18.6(  1%(

   EB LEFT    360  1800    20   144.72   2.04   20.4   0.00    0.03    0.03    0.3     0.0(  0%)   4.0(  2%)   4.0(  2%(

   3248     : 3     MAX =  53  1305.70  18.47          0.00    0.33    0.33    0.4     0.0(  0%)  22.6(  1%)  22.6(  1%(
--------------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------           veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (    0)  0.6 (    1)  0.6 (    1)157.0 ( 399)   0.0    N      11.76  20.0     6

   EB LEFT   0.0 (    0)  0.1 (    1)  0.1 (    1) 53.0 ( 404)   0.0    N      11.76  20.0     6

) 106.38          0                                                     : 3     DI=    0.5      (
--------------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   3248  5400    60  1305.70  18.59   20.6   0.00    0.45    0.45    0.5     0.0(  0%)  24.4(  1%)  24.4(  1%(

   WB RGHT    420  1800 99900*  168.841050.00 9000.0  47.66 1000.00 1047.66 8979.9   420.0(100%)1000.0(239%)1420.0(339%(

   3668     : 4     MAX =***** 1474.541068.59         47.66 1000.45 1048.11 1028.7   420.0( 11%)1024.4( 28%)1444.4( 39%(
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %               lit   sec
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.8 (   2)  0.8 (   2)156.0 ( 396)   0.0    N     ******  20.0     6

   WB RGHT  61.3 ( 465)***** (7620)***** (8085)  43.0 ( 328)   0.0    N     ******  20.0     6

) 3044.33        0                                                     : 4     DI=  785.4      (
-----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                (vph(%,
-----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2745  5400    51  1103.49  15.59   20.4   0.00    0.26    0.26    0.3     0.0(  0%)  16.7(  1%)  16.7(  1%(
      RGHT    923  1800    51   371.05   5.42   21.1   0.00    0.27    0.27    1.0     0.0(  0%)  17.0(  2%)  17.0(  2%(

   3668     : 5     MAX =  51  1474.54  21.01          0.00    0.53    0.53    0.5     0.0(  0%)  33.7(  1%)  33.7(  1%(
-----------------------------------------------------------------------------------------------------------------------------
----
```

```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N      30.71  20.0     6
      RGHT   0.0 (   0)  0.5 (   4)  0.5 (   4) 52.0 ( 396)   0.0    N      30.71  20.0     6

) 120.57         0                                                         : 5     DI=    0.8      (
----------------------------------------------------------------------------------------------------------------------------
----

 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.          Flow  of Sat  Travel  Total   Avg  Uniform Random    Total Average    Uniform     Random      Total
             vph   vphg    %     veh-km  veh-h sec/v         veh-h            sec/veh                (vph(%,
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2745  5400    51  1103.49  15.59   20.4   0.00    0.26    0.26    0.3     0.0(  0%)  16.7(  1%)  16.7(  1%(

   WB RGHT    200  1800 99900*   80.401023.2318418.1  22.11 1000.00 1022.1118398.0   200.0(100%)1000.0(501%)1200.0(601%(

   2945     : 6     MAX =***** 1183.891038.82         22.11 1000.26 1022.37 1249.8   200.0(  7%)1016.7( 35%)1216.7( 41%(
----------------------------------------------------------------------------------------------------------------------------
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 Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform       Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
----------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   0.0 (   0)  0.5 (   1)  0.5 (   1)157.0 ( 399)   0.0    N     ******  20.0     6

   WB RGHT  28.6 ( 221)***** (7620)***** (7841) 47.0 ( 358)   0.0    N     ******  20.0     6

) 2939.27        0                                                         : 6     DI=  763.7      (
----------------------------------------------------------------------------------------------------------------------------
----
```

```
 Movement/   Flow   Sat  Degree  Total   Travel Time  ------------ Delay -----------   ------------- Stops-------------
 Node No.           Flow  of Sat  Travel  Total   Avg  Uniform Random   Total Average    Uniform      Random       Total
             vph    vphg    %     veh-km  veh-h sec/v          veh-h            sec/veh                 (vph(%,
-------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU   2870   3600P  179* 1153.74 375.85  471.5  74.83  285.00  359.83  451.4  2584.4( 90%)1000.0( 35%)3584.4(125%(

   SB THRU    930   3600   152*  373.86 132.87  514.3  65.31   62.37  127.67  494.2   930.0(100%) 566.2( 61%)1496.2(161%(
      LEFT    375   1800   122*  150.75  33.54  322.0  18.27   13.18   31.45  301.9   314.8( 84%) 148.3( 40%) 463.1(124%(
      RGHT    180   1800    59    72.36   5.90  118.0   4.49    0.40    4.90   97.9   103.9( 58%)   9.4(  6%) 113.3( 63%(

   EB THRU    520   3600P  124*  209.04  37.40  258.9  15.98   18.52   34.50  238.8   520.0(100%) 205.1( 40%) 725.1(140%(
      RGHT    240   1800   104*   96.48  14.05  210.7   7.93    4.78   12.71  190.6   205.9( 86%)  62.9( 27%) 268.8(112%(

   WB THRU    320   1800   139*  128.64  43.41  488.3  23.72   17.90   41.62  468.2   320.0(100%) 177.0( 56%) 497.0(156%(
      LEFT    700   1800   305*  281.40 281.67 1448.6  96.34  181.42  277.76 1428.5   700.0(100%) 820.5(118%)1520.5(218%(
      RGHT    120   1800    52    48.24   4.14  124.2   3.19    0.28    3.47  104.1   110.1( 92%)   7.3(  7%) 117.4( 98%(

(%51 )25.4  (%1  )0.4   (%50 )25.0    30.1   0.42    0.00    0.42   50.2   0.70   20.10    6     1800  50      713   7
(%50 )12.5  (%1  )0.2   (%49 )12.3    29.6   0.21    0.00    0.21   49.7   0.35   10.05    3     1800  25      714   7
(%77 )38.2  (%4  )1.9   (%73 )36.3    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      715   7
(%92 )45.9  (%4  )1.9   (%88 )44.0    94.2   1.31    0.03    1.28   114.3  1.59   20.10    22    1800  50      716   7

   6430     : 7     MAX = 305* 2584.86 933.05        313.24  583.90  897.14  502.3  5906.7( 92%)3001.1( 47%)8907.8(139%(
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```
Movement/  -------- Max Back of Queue --------    Queuing   Time  Critical  Fuel  Eff.    Arr.
 Node No.   Uniform        Random       Total     Capacity   Full  Link      Cons. Green   Type   LOS
--------------            veh/link( m/lane)---------------     %              lit   sec
--------------------------------------------------------------------------------------------------------------------------------
----

   NB THRU 185.3 ( 705)159.3 ( 607)344.5 (1312)105.0 ( 400)   0.0    N     ****** 118.0     3      F

   SB THRU  88.9 ( 339) 41.1 ( 156)130.0 ( 495) 89.0 ( 339)   0.0    N     427.42  40.0     3      F
      LEFT  28.7 ( 221) 10.8 (  82) 39.5 ( 303) 44.0 ( 335)   0.0    N     114.01  40.0     3      F
      RGHT  10.4 (  76)  0.7 (   5) 11.1 (  81) 52.0 ( 396)   0.0    N      24.25  40.0     3      F

   EB THRU  29.3 ( 110) 14.9 (  57) 44.1 ( 167)105.0 ( 400)   0.0    N     136.72  30.0     3      F
      RGHT  15.7 ( 122)  4.6 (  35) 20.2 ( 157) 47.0 ( 358)   0.0    N      52.60  30.0     3      F

   WB THRU  33.9 ( 259) 12.8 (  98) 46.7 ( 357) 45.0 ( 343)   0.0    N     140.67  30.0     3      F
      LEFT 126.5 ( 968) 59.5 ( 453)186.0 (1421) 39.0 ( 297)   0.0    N     825.34  30.0     3      F
      RGHT   7.1 (  53)  0.5 (   4)  7.7 (  57) 52.0 ( 396)   0.0    N      18.64  30.0     3      F

    0.0   (404 ) 53.0 (15  ) 1.7  (0   ) 0.0  (15  ) 1.7   713   7   N       3.95 118.0     3      C
    0.0   (404 ) 53.0 (8   ) 0.8  (0   ) 0.0  (8   ) 0.8   714   7   N       1.95 118.0     3      C
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   715   7   N       6.94  30.0     3      F
    0.0   (404 ) 53.0 (24  ) 3.0  (1   ) 0.1  (23  ) 2.9   716   7   N       7.30  30.0     3      F

) 2970.77        0                                                     : 7     DI=  766.6)     F
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All MOEs are in units per hour .

SYSTEM-WIDE PERFORMANCE: ALL NODES

Performance Measures	Units	System Totals
Total Travel	veh-km/hr	14311
Total Travel Time	veh-hr/hr	6511
Total Uniform Delay	veh-hr/hr	1380
Total Random Delay	veh-hr/hr	4932
Total Delay	veh-hr/hr	6312
Average Delay	sec/veh	638.3
Passenger Delay	pax-hr/hr	7574
Uniform Stops:	veh/hr	17786
%		50
Random Stops:	veh/hr	12398
%		35
Total Stops:	veh/hr	30184
%		85
Degree of Sat > 1	# of links	19
Queue Spillback	# of links	15
Time Jammed	%	0
Period Length	sec	900
System Speed	km/hr	2.2
Fuel Consumption	lit/hr	19482
Operating Cost	$/hr	22778
Performance Index	DI	4994 .

Performance Index (PI): Disutility Index (DI:(
Disutility Index Excess Fuel Consumption

REFERENCES

Al-Washykree, A. (2012). Facsimile Memorandum, Statistical Department of the Directorate General of Traffic, Ministry of Interior, Saudi Arabia, 13 June, 2012

Barnard, Y., Risser, R., and Krems, J. (2011). The Safety of Intelligent Driver Support Systems, Ashgate Publishing Company, Farnham.

Ben-Akiva, M. and Lerman, S.R. (1985). “Discrete choice analysis: Theory and application to travel demand”, Transportation Research Board, Washington D.C.

Berkson, J. (1944). “Application of the logistic function to bio-assay”, Journal of the American Statistical Association., Vol. 39, No. 227, pp. 357-365.

CEN – European Committee for Standardization (2005). EN 12966-1:2005, E. Brussels, Belgium.

Chang, J. and Russell, M. (2010). “How well do New Zealand drivers understand variable message signs?”, Technical Paper, IPENZ Transportation Group Christchurch, Opus International Consultants Ltd.

Chatterjee, K., Hounsell, N., Firmin, P., and Bonsall, P. (2002). “Driver response to variable message sign information in London”, Transportation Research Part C: Emerging Technologies, Vol. 10, No. 2, pp. 149-169.

Cramer, J. (2001). An Introduction to the Logit Model for Economists, 2nd Edition, Timbarlake Consultants.

Davidsson, F. and Taylor, N. (2003). “ITS modelling in Sweden using CONTRAM”, TRL Report 2003/04, Berkshire, United Kingdom.

Edara, P., Sun, C., Keller, C., and Hou, Y. (2012). “Evaluating the benefits of dynamic message signs on Missouri’s rural corridors”, Final Report prepared for Missouri Department of Transportation , Project TRyy0947.

Erke, A., Sagberg, F., and Hagman, R. (2007). “Effects of route guidance variable message signs (VMS) on driver behavior”, Transportation Research Part F: Traffic Psychology and Behavior, Vol. 10, No. 6, pp. 447-457.

Florida Department of Transportation (2008). “Guidelines for the use of dynamic message signs on Florida’s State Highway System”, 080925 DMS Guidelines_V1_4_final.doc

Høye, A., Sørensen, M., Elvik, R., and Akhtar, J. (2011). "Evaluation of variable message signs in Trondheim Tor-Olav Nævestad, Truls Vaa Oslo", TØI Report 1153, 263 pages, in Norwegian language.

Hustad, M.W. and Dudek, C.L. (1999). "Driver understanding of abbreviations on changeable message signs in New Jersey". Transportation Research Record 1689, Transportation Research Board, Washington D.C., pp. 46-52.

INRIX (2008), "The impact of fuel prices on consumer behavior and traffic congestion", INRIX Special Report.

Jamson, S.L. (2004). "Evaluation of techniques to improve the legibility of bilingual variable message signs", Advances in Transportation Studies: An International Journal, Vol. 4, pp. 71-88.

Kronborg. P. (2001). "VMS för omledning", Movea Trafikkonsult AB, Stockholm, Sweden. Available: <http://www.movea.se/vms_omled.pdf> [2006-02-06].

Lim, I.-K. (2005). "An analysis of CMS impact on incident-based congestion", A PhD Dissertation submitted to Michigan State University.

Litman, T. (2006). "Evaluating transportation land use impacts", Victoria Transport Policy.

Litman, T. (2009). "Congestion costs", Transportation Cost and Benefit Analysis; Techniques, Estimates and Implications, Victoria Transport Policy.

Ministry of Interior (2011). Statistical Department of the Directorate General of Traffic, Ministry of Interior, Kingdom of Saudi Arabia.

New York State Department of Transportation (1996). "Best practices in arterial management", Corridor Management Group.

Peeta, S. and Ramos, J.L. (2006). "Driver response to variable message signs-based traffic information", IEE Proceedings, Intelligent Transport Systems, Vol. 153, No. 1.

Peeta, S., Ramos, J.L., and Pasupathy, R. (2006. "Content of variable message signs and on-line driver behavior", Transportation Research Record 1725, Paper No. 00-0970, School of Civil Engineering, Purdue University, West Lafayette, IN 47906.

Polydoropoulou, A., Ben-Akiva, M., and Kaysi, I. (1994). "Influence of traffic information on drivers' route choice behavior", Transportation Research Record 1453, Transportation Research Board, Washington, D.C., pp. 56-65.

Ran, B., Barrett, B., and Johnson, E. (2004). “Evaluation of variable message signs in Wisconsin: Driver survey”, Final Report No. 0092-45-17, Wisconsin Department of Transportation Research, Development & Technology Transfer.

Richards, A. and McDonald. M, (2007). “Questionnaire surveys to evaluate user response to variable message signs in an urban network”, IEEE Proceedings, Intelligent Transport Systems, Vol. 1, No. 3.

Sara, N, and Gabriel, H, (2007). “VMS – Variable message signs – A literature review”, VTI Rapport 570A.

Schiesel, R.B. and Demetsky, M.J. (2000). “Evaluation of traveler diversion due to en-route information”, Report No. UVA/29472/CE00/103.

Shirazi, E., Anderson, S., and Stesney, J. (1988). “Commuters’ attitudes toward traffic information systems and route diversion”, Transportation Research Record 1168, Transportation Research Board, Washington D.C., pp. 9-15.

Turnbull, K. (2001), “Evolution of high-occupancy vehicle facilities,” TR News 214 (Special HOV Issue), Transportation Research Board, pp. 6-11.

University of Wisconsin (2001). “Evaluation of variable message signs in Wisconsin: Driver survey statewide”, Wisconsin, United States.

Wang, J.H., Collyer, C.E., and Yang, C.M. (2006). “Enhancing motorist understanding of variable message signs”, FHWA-RIDOT-RTD-06-1, University of Rhode Island, Kingston, RI 02881.

Wenger, M.J., Spyridakis, J.H.. Haselkom, M.P., Barfield, W., and Conquest, L. (1990). “Motorist behavior and the design of motorist information systems”, Transportation Research Record 1281, Transportation Research Board, Washington, D.C., pp. 159-167.

Yang, C.-M., Waters, D., Cabrera1, C.C., Wang, J.-H., and Collyer, C.E. (2004). “Enhancing the messages displayed on dynamic message signs”, Proceedings of the Third International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, University of Rhode Island, Kingston, Rhode Island, USA (Accessed 2012).

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